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Panel Survey Issues in the Evaluation of the Singapore North-East Line (NEL) and the Sengkang Light Rail Transit (SKLRT)

A.J. Richardson

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Table of Contents

1 Background

The Singapore North East Line (NEL) and the Sengkang Light Rail Transit (SKLRT) will open by the end of March 2003. Both of these lines form part of Singapore's Rapid Transit System (RTS) aimed at achieving the Land Transport Authority's (LTA) mission, which is *"To provide a quality, integrated and efficient land transport system which meets the needs and expectations of Singaporeans, supports economic and environmental goals, and provides value for money*". The NEL is a strategic Mass Rapid Transit (MRT) line 20km long linking the northeast of Singapore to the central business district (CBD). This includes interchanges with the existing North-South and East-West lines at Dhoby Ghaut and Outram Park respectively. SKLRT is a 10.7km long LRT system with 14 stations constructed entirely on a viaduct connecting the Sengkang area to the NEL at Sengkang station.

Scott Wilson Transportation Planning (SWTP) have been engaged by the LTA to provide consulting services in the evaluation of the impact of the opening of the NEL and SKLRT. The overall objectives of the study, as specified in the LTA terms of reference, are:

- To capture the impact of NEL and SKLRT on travel patterns and behaviour of travellers within its corridor;
- To improve the model prediction of travel behaviour using the data collected; and
- To obtain the public perception of the NEL and SKLRT.

Specifically, the components of the project are:

- To undertake a "before opening" survey in late-2002, comprising a face to face interview household interview survey with residents within the NEL and SKLRT corridor. This survey will collect comprehensive travel pattern data including origin and destination of all trips, frequency, purpose, mode of travel, journey time and cost on a typical weekday for all persons above 6 years of age in a household;
- To undertake an "after opening" survey in mid-2003 comprising face to face interviews with the same residents as in the "before opening" surveys. This will be used to identify changes in travel behaviour such as trip generation rates and mode shift due to the new lines;
- To undertake extensive passenger surveys of NEL/SKLRT passengers after opening to capture the travel characteristics of the current trip;
- Analyse other before and after data to assess the impact of the NEL and SKLRT, such as bus and MRT patronage figures from Transit Link and vehicular traffic counts from the LTA;
- Undertake all sampling, survey design, fieldwork for the above surveys;
- Analyse all data (both survey data and other data) to identify changes in travel behaviour before and after the opening of the NEL/SKLRT, and the reason for the changes;
- Review the LTA model forecast of NEL and SKLRT opening year patronage in terms of total boardings and line loadings, and station boarding/alighting for the morning, evening and off-peak time periods; and
- Update and enhance the Authority's model in light of the findings above.

The Urban Transport Institute (TUTI) has been engaged by SWTP as a sub-consultant to provide specialist advice on the design, conduct and analysis of the various surveys to be conducted as part of the project.

It is anticipated that some form of panel survey will be used to measure the change in behaviour of households after introduction of the Singapore North East Line (NEL) and the Sengkang Light Rail Transit (SKLRT). The purpose of this report, therefore, is to advise on issues that need to be considered in the design of such a panel survey. It does this by considering the range of biases that needed to be accounted for in the design, conduct and analysis of panel surveys.

2 Weighting and Biases in Panel Surveys

While most travel surveys are sample surveys, it is rare that the behaviour of the sample is the prime concern of the analyst. Rather, the sample is usually used as a way of obtaining insights into the behaviour of a larger population. However, it is often the case that the sample is not truly representative of the population, and that a variety of biases have entered into the sample data that make it un-representative of the population. Such biases in travel surveys are often accounted for by post-stratification or weighting of the sample results. A fundamental issue in the development of "weights" is the "population" to which the sample data is being expanded and weighted. In demographic surveys, the population is usually defined as a collection of people or households in the study area. For travel surveys, this may not be sufficient since the true focus of attention is the travel characteristics of this population, and not the demographics of the population. Therefore, expanding and weighting travel survey data only on the basis of demographic characteristics may not be sufficient where, for example, the demographics of respondents and non-respondents may be similar but the travel characteristics of respondents may be different to the travel characteristics of non-respondents.

Being a panel survey, the proposed NEL Evaluation Survey (NELES) requires weighting at two distinct stages: weighting of the data from the initial sample drawn in Wave 1 to account for various forms of bias in the initial survey, and weighting of the data from subsequent Waves to account for the biases specifically created within panels surveys (Tourangeau, et al., 1997). This report outlines an "holistic" approach to weighting where all potential sources of bias are considered in the context of both their likely magnitude and their relevance to the likely use of the TES. As noted by Horowitz (1997), the effects of non-response in the initial sample are ignored "by most analysts who work with panel data, but its effects are just as pernicious as those of attrition". The same could be said of several other forms of bias often not addressed in panel survey data. A catalog of the different forms of bias in both stages of a panel survey are described below.

3 Potential Biases in the Initial Sample

The following biases can occur in all surveys, not just panel surveys. However, the generality of these biases does not mean they can be ignored in panel surveys. They apply just as much to panel surveys as they do to cross-sectional surveys. Even if close attention is paid to the biases specific to panel surveys that will be described in the next chapter, lack of attention to the biases described in this chapter will mean that the panel survey has started with a biased sample which may not be correctable in later waves of the panel survey.

Coverage bias

Coverage bias refers to the extent to which the sample frame used to draw the sample correctly represents the population of interest. Sample frames can be deficient because of inaccuracies in the frame (mis-spellings etc), incompleteness (not all members of the population included), duplication (some members of the population included more than once), inadequacy (the frame is simply not a good approximation to the desired population), or timeliness (the frame is not up-to-date).

Sample bias

Sample bias refers to the way in which the sample was drawn from the sample frame. Unless random sampling is used throughout the process (i.e. equal probability of selection, independence of selection), biases can be introduced (such as preferential sampling on the part of the interviewer, or self-selection on the part of the respondent). Sometimes (as in the use of unequal sampling fractions in stratified sampling) a bias is deliberately introduced by the surveyor with the intention of correcting this bias in the analysis phase.

Choice-based sampling bias

Where a population contains rare sub-groups of interest, such as transit riders, sampling may be undertaken for those sub-groups by means of choice-based sampling, whereby sampling is performed in situations where it is known that those sub-groups exist (e.g. by sampling on-board transit vehicles). A problem exists when choice-based sampling is used for one sub-group while other sampling methods (such as Random Digit Dialling) are used for the general population. In this case, the rare sub-group will be over-represented in the total sample, and must be weighted downwards in the overall weighting process.

Non-contact bias

For those sampling units selected in the sample, an attempt is made to contact them (either by mail, phone or in person). Some of these sampling units (households) will not be contactable, even after repeated attempts. If the reason for not contacting them is related to the parameter of interest (in this case their travel behavior) then a bias will result. In the case of telephone and personal contacts, a major reason for non-contact is that the people in these households are out of home travelling at the time of the attempted contact. This is more likely to occur for small households and highly mobile households, thereby introducing a bias into the characteristics of the households actually contacted.

Unit Non-response bias

A major problem affecting all surveys, not just panel surveys, is unit non-response, where the sampled units in the population (e.g. households) who are contacted choose not to respond to the survey. If this non-response is randomly distributed in the population, then there is no specific bias introduced (although the reduced number of responses will have an effect on the level of statistical sampling error). However, if this non-response is not randomly distributed in the population, then there are two possible problems. Firstly, the non-respondents may be different demographically to the respondents (this can be corrected by demographic weighting and post-stratification of the sample to match a larger demographic survey such as

the Census). Secondly, and a more insidious problem in travel surveys, the non-respondents may be similar demographically to the respondents but their travel characteristics may be different (e.g. people within a demographic groups who make more trips may find it more burdensome to complete the survey, and hence decline to do so. Alternatively, people who make few trips may perceive that the survey is not addressed to them, and hence decline to complete the survey). In the context of the NELES, it is possible that households who are less affected by the opening of the NEL may be less willing to make the time to complete the surveys.

An issue that is related to unit non-response bias is the definition of a responding household. Where very strict definitions of a responding household are applied (e.g. no missing persons or data allowed at all), there is more potential for bias because large households and highly mobile households have more scope for missing data. If responding households with missing persons or data are excluded from the data set, then there will be a bias towards small households and households that make fewer trips.

Item Non-response bias

Within responding households there will generally be some degree of item non-response (i.e. missing data for specific questions). To the extent that the missing data is different from the data supplied by other respondents, then there is scope for item non-response bias. For example, it has been found in many surveys that non-responses to the income question tend to be at the ends of the income spectrum, with more higher than lower income people not providing an answer. Such biases need to be corrected, probably by the use of an appropriate imputation procedure, rather than assuming that the respondents are representative of the non-respondents to this question.

Non-reported trip bias

A particularly difficult type of bias to identify is the non-reported trip bias, where respondents simply don't report certain types of trip (it is difficult to identify when we don't know in advance what their trip-making really is!). The extent of non-reporting of trips depends on the type of survey method employed and the extent of probing used to identify missing trips. Previous research has identified short, non-motorized trips for discretionary purposes as being the type of trip to be most likely to go unreported.

Proxy response bias

Non-reporting (and inaccurate reporting) of travel is more likely to occur when proxy reporting is allowed (i.e. one household member is allowed to report travel on behalf of another member of the household). Proxy reporting is especially likely to result in biased reporting for non-home-based trips made during the middle of the day (e.g. trips to and from work at lunchtime, and work-based business trips).

Measurement bias

Measurement bias occurs when the questions used within the survey are poorly designed, leading to biased answers. There are many types of measurement bias, arising from poor or ambiguous wording, leading questions, selective mention of alternative answers, or poor

choice of category responses (leading to primacy, recency or range biases). A thorough examination of the survey instrument is required to identify such potential measurement biases.

Multiday fatigue bias

Some before and after surveys use a 7-day diary to record travel patterns. Previous multi-day panel surveys have reported problems with multi-day diaries. The Puget Sound Transportation Panel (PSTP) (Murakami and Ulberg, 1997) has identified a degree of respondent fatigue on the second day, with lower trip rates reported on the second of the two days. In the Dutch National Mobility Panel (DNMP), which used a 7-day diary, Meurs (1991) also reported multiday fatigue effects. Such biases need correction if an unbiased estimate of total travel is to be obtained.

Seasonal bias

A further dimension of the total "population" needs to be specified with respect to the temporal dimension. If the "population" is defined as a full year, or an average day in the year, then any seasonal bias that is caused by the timing of the survey must be corrected. Since the NELES will be conducted over a limited time period in the year, such correction will be needed if average day results are to be obtained. A similar problem occurs if the survey is not uniformly distributed over the days of the week within the survey period.

Incentive bias

In order to improve response rates, incentives are often used to encourage people to respond. However, while some incentives have proved successful in increasing the number of respondents, it must be ascertained whether the increased response is a random or biased sample of the total respondents. Some types of incentive might be more attractive to particular groups in the community (who may also have different travel patterns). Therefore, incentives should be checked for their potential biasing effect, as well as their response-increasing effect.

4 Potential Biases in the Following Waves

The following biases are specifically associated with panel surveys. While they are the biases most often mentioned when talking about panel surveys, they should not be considered to the exclusion of the biases identified in the previous chapter. Both sets of biases must be accounted for if an unbiased panel survey is to be conducted.

Coverage bias

The coverage biases identified for the initial wave of the panel will continue into the subsequent waves, especially where the same sampling frame is used to select replacement households. Indeed, as time passes, the initial sampling frame will become more out-of-date unless it is updated each year.

Attrition bias

The major type of bias usually identified for panel surveys is attrition bias (sometimes referred to as sample mortality, from its original usage in epidemiological panel studies). Attrition bias refers to the reduction in the size of the panel as time progresses, as households drop out for a variety of reasons. It should be recognized that attrition bias actually covers a range of reasons for drop-out, such as real mortality, moving out of the target population (e.g. out of the region), loss of interest, and all the reasons for non-response in cross-sectional surveys such as non-contactability, lack of time, inconvenient timing of the survey, and perceptions of survey burden. As with non-response in the initial survey, if this attrition is randomly distributed in the population, then there is no specific bias introduced (although the reduced number of responses will have an effect on the level of statistical sampling error). However, if this attrition is not randomly distributed in the population, but is correlated with a parameter of interest in the survey (such as travel behavior) then attrition can be a considerable source of bias. This is especially the case in a panel survey that runs for a large number of waves, such as the PSTP and the DNMP. For example, Meurs and Ridder (1997) report that after 10 waves of the DNMP, only 33% of the original Wave 1 participants were left in the survey. It is highly unlikely that these 33% are representative (either demographically or travel behavior wise) of the original Wave 1 participants. In the PSTP, only 55% of Wave 1 participants were remaining by Wave 4 (compared to 53% by Wave 4 in the DNMP). Once the proportion of original participants has fallen to such levels, it is doubtful whether the true benefits of a panel survey are being achieved. In addition, the remaining participants are unlikely to be a representative cross-section of the population, even if the Wave 1 respondents were themselves representative. Using all waves of the panel to represent an ongoing cross-section of the population under these conditions is unlikely without significant effort being made to correct for attrition bias. Attrition weights are often calculated (and applied to the stayers from the Wave n) such that the weighted composition of Wave n+1 is the same as the composition of Wave n.

Refreshment bias

In an effort to maintain a constant sample size across all waves of a panel survey, it is common practice to replace the participants who drop out with a new sample of respondents from the target population. Often these new respondents are selected to match the demographics of those participants who dropped out of the panel, so that the overall demographic composition of the panel remains fairly constant. However, there are two potential problems with this approach. Firstly, while the replacements may be demographically similar to those leaving the panel, they may have very different travel characteristics, especially if those leaving the panel have done so for reasons related to the mobility patterns. Thus while the demographics of Wave 2 may be similar to the demographics of Wave 1, the travel patterns may be substantially different. Secondly, if attrition weights have already been calculated and applied to the stayers from Wave 1 in order to make up for those who left the panel, then adding refreshments with the characteristics of the leavers will double count this group in the Wave 1 weighted results. The treatment of attrition and refreshment bias must therefore be done concurrently, rather than separately.

Demographic shift bias

While the sample in Wave 1 might be representative of the target population in year 1, it is possible, especially in areas experiencing rapid growth, that the size and composition of the

target population will have changed by year 2. Thus the sample in Wave 2 must now be representative of the target population in year 2, after allowing for the shift in demographics of the population between Wave 1 and Wave 2. Once again, this effect is magnified when the panel survey runs over many years, as is the case in the DNMP and the PSTP. For this reason, one cannot use a static description of the target population, but must update it over time.

Household composition bias

As time progresses, households may elect to remain in the panel survey but the composition of their household may change significantly. Births, deaths, marriages, separations, remarriages and many other changes may cause the splitting and merging of households over the extended period covered by all waves of the NELES. A design decision must be made in the initial stages of the NELES as to whether to try to track all members of the original households while they remained in the study area, and whether to attempt to recruit new members of the original households. The success in achieving this goal must be monitored, and any biases resulting from such changes in household composition (such as a gradual decline in household size) must be identified and corrected.

Panel fatigue bias

As households participate in more waves of the panel, there can be conditioning or fatigue effects, whereby their response to later waves is conditioned on the fact that they have already participated in several earlier waves. This conditioning can potentially be very biasing, with apparent trends in behavior being due not to real changes in behavior but to changes in the way that the behavior is reported. For example, Meurs (1991) reports that over seven waves of the DNMP, the extent of trip under-reporting grew from 2.3 trips per person per week (26 minutes of travel) to 8.4 trips per person per week (100 minutes of travel). The effect of this bias is clearly worrying in the DNMP, since Mears and Ridder (1997) conclude that "estimating a trend in mobility from the DNMP is not possible" since "the DNMP exhibits a spurious downward trend in mobility, and the level of mobility is positively related to the number of waves in which the household remains in the panel". If such trends are to be obtained from the NELES, then clearly the biasing effect of panel fatigue on measures of mobility will need to be identified and corrected.

Seasonal bias

While seasonal bias is a problem for any survey not conducted over a full year, as described earlier, it is even more of a problem when the survey is conducted at different times of the year in different Waves of the panel. If each year is corrected for seasonal bias and adjusted to represent the entire year, then the problem is resolved. However, if the individual waves are not adjusted to the full year, then special corrections need to be made to those Waves conducted in different seasons of the year.

Procedural change bias

If comparisons are to be made between different waves of a panel, then it is clear that the survey methods should remain unchanged from wave to wave. However, for a variety of practical reasons, it is possible that changes were made to the sampling, the questionnaire, the methods of conduct, and the coding and editing of the data. The effect of each of these

changes will need to be identified to determine whether they could have introduced any significant biases into the comparison of results from wave to wave.

5 Conclusions

The preceding chapters have identified a list of possible biases that might occur in a panel survey. Having identified all these possible sources of bias in panel surveys, it should be emphasized that not all of the biases listed above will appear in the NELES data. It should also be emphasized that operational weighting strategies may not be able to be implemented for all the biases identified above, mainly because the secondary data needed to identify or correct the bias may not be available. However, it is considered important to be holistic in the identification of the potential biases so that the significance of those biases that can be corrected can be placed into context alongside all the other biases (whether they be correctable or not). There is little point being highly technical and precise in the correction of some biases, if other more significant biases are left unidentified and uncorrected.

6 References

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