DATA AND MEASUREMENT ISSUES IN TRANSPORTATION, WITH TELECOMMUTING AS A CASE STUDY

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ABSTRACT

Using transportation and other social science data examples, and focusing in depth on telecommuting, we demonstrate that definitions, measurement instruments, sampling and sometimes vested interests affect the quality and utility even of seemingly objective and "measurable" data. Little consensus exists with respect to the definition of telecommuting, or to possible distinctions from related terms such as teleworking. Such a consensus is unlikely, since the "best" definition of telecommuting depends on one's point of reference and purpose. However, differing definitions confound efforts to measure the amount of telecommuting and how it is changing over time. This paper evaluates estimates of the amounts of telecommuting occurring in the U. S. obtained from several different sources: the U. S. Census, the American Housing Survey, several Work at Home supplements to the Current Population Survey, a series of market research surveys, and the trade association-sponsored Telework America surveys. Many of the issues raised here are transferable to other contexts, and indirectly serve as suggestions for improving data collection in the future.

Keywords: telecommuting, teleworking, data quality, measurement issues, social science data, transportation impacts of telecommuting

1. INTRODUCTION

Measurement issues lie at the heart of empirical and policy studies. Without the appropriate quality and quantity of data, it becomes impossible to assess situations, trends and projections for the future. Social scientists have devoted much attention to issues of measurement and to the development of research instruments that improve the quality of data. Much of this attention has focused on problems associated with qualitative factors, such as those described in the book *Measuring the Unmeasurable* (Nijkamp, *et al.*, 1983).

The introduction of behavioral research into the transportation field over the last three decades has confronted researchers with the need to incorporate various factors that are borrowed from psychology, sociology and other fields. Many of these involve factors that are clearly subjective and that relate to personality traits for which measurement tools introduce a significant inaccuracy into quantitative modeling efforts. Some obvious examples are the value of time, which for a single individual may change almost momentarily; and the real out of pocket costs of travel, which are subject to wide variation associated with vehicle type and condition, driving patterns and traffic flow patterns.

The conventional approach to dealing with such problems in transportation has been the adoption of various assumptions regarding the factors and the data that represent those factors. A simple example is the adoption of "engineering data" such as a mechanical network-based calculation of distance or travel time to reported origin-destination pairs, even though individuals' qualitative perception of the distance or time may be more relevant to their travel decisions (Koppelman, 1981).

In social science research, however, the role of subjectivity is a concern not only with respect to capturing relevant traits of the population of interest, but also insofar as it relates to the researchers themselves. The incorporation of analysts' values into the process of model-building and forecasting is well-known (e.g. Moore, 1993; Pickrell, 1992; Skamris and Flyvbjerg, 1997; Wachs, 1989; Wallace, 1994), and not discussed further here. Instead, we focus on the even simpler issue of the data inputs to such models and forecasts. We emphasize that even at this most elemental level of analysis, "objectively measurable" quantities can be influenced by the subjectivity of the analyst.

Thus, this paper makes a distinction between measurable and "unmeasurable" input variables and addresses what may seem quite trivial, namely, the measurement of clearly objective quantities. By measurable we mean that a phenomenon is of a finite value, at a given time and place, and that this value can be gauged in a consistent manner. Repeated measurement should produce consistent results.

Using telecommuting as a case study, we explore several different issues with respect to the assessment of the extent to which it is occurring – certainly an objective, "measurable" characteristic. Issues we address include the importance of context, the need for a definition that is consistent and at a relevant level of precision (Churchman, 1959), the potential impacts of sampling variance and bias, the potential for personality or ideology to skew the measurement process and the interpretation of the results, and the tendency to treat personal experience or anecdotal information as representative. We briefly present a number of other examples from

social science research that illustrate these issues as well. The result in many cases is multiple sets of data that are widely divergent, constraining the quality of analysis that can be conducted and clouding the dialogue that takes place on the subject. This is certainly true with respect to telecommuting, as we will demonstrate in detail in succeeding sections. Our hope is that this paper will be of value both as an assessment of specific measurement issues and sources with respect to telecommuting, but also as an example of a more general set of issues to consider in collecting and evaluating data of many kinds.

The organization of the remainder of this paper is as follows. In Section 2 we offer several instances from transportation and other social science data sources, illustrating some of the issues we raise in this paper. In Section 3 we introduce the in-depth case study of telecommuting. Section 4 discusses the importance of context to measuring telecommuting, and places the current paper in the particular context of studying the transportation impacts of telecommuting. Section 5 identifies some issues to consider in evaluating the definition, quality, and quantity of data on the number of telecommuters in the U.S., and applies those considerations to evaluating several data sources with respect to their suitability for a study of the transportation impacts. In Section 6 we discuss issues relating to measuring telecommuting frequency. Although in both sections we take a transportation perspective, most of the issues raised are generalizable to other contexts of interest. Section 7 offers some concluding remarks.

2. EXAMPLES FROM SELECTED SOCIAL SCIENCE DATA SOURCES

Although telecommuting is the example explored in depth here, the issues raised are by no means unique to that context. Maier (1991), for example, points out that even simple demographic data collected by the U. S. Census (population, ethnicity, marital status) are subject to sampling bias (e.g. undercounts of the homeless and undocumented populations) and definitional ambiguities (e.g. differences between the official and the commonly-understood definitions of terms such as “household” and “family”). He comments that there is a conflict of interest in having the same agencies (the local police and the Federal Bureau of Investigation) that are responsible for law enforcement collect and report data on crimes – resulting in well-known underreporting by specific police precincts in the past. Maier elaborates on a number of other public policy contexts (housing, health, education, the economy, government) in which the same data generates contradictory conclusions by different people, and explores how some of the issues raised here contribute to those outcomes.

Smith (1995) discusses a number of dimensions related to defining the seemingly simple variable of educational attainment. He points out (p. 238) that despite the position of education as the single most important explanatory variable in social science research, “The standard way of measuring education by assessing years of schooling or highest degree obtained probably captures the single most important aspect of education, but it rarely measures that aspect thoroughly and also almost totally neglects other important aspects”. The failure to account for various aspects of the education construct, he notes (p. 220), can “misspecify the impact of education in a wide range of models”.

The examination by Raley, *et al.* (2000) of data on child care has several parallels to our study of telecommuting measurement. As we do for telecommuting, they compare the measurement of

the occurrence of child care reported in several large-sample nationwide (U.S.) data sets, and find substantial variation. A key observation is that the context of the survey design (e.g. whether the focus is on the impact of children on mothers' employment, versus the impact of child care on children independently of the mother's employment status) affected which potential respondents were surveyed (e.g. mothers only, or either parent) and the extent of child care that was measured (e.g. only child care that occurred while the mother was working, versus all child care). Variances in definitions (e.g. identified categories of child care) and other question wording, and in sampling practices (e.g. the extent of data collection in the summer, and the age cohorts of the mothers sampled), also affected the results.

Transportation systems seem to involve many objectively measurable attributes, but a careful examination of some will reveal serious flaws in this assumption. Some examples are noteworthy.

The measurement of aggregate vehicle-miles traveled is difficult. Yet, it is an important parameter for policy analyses, as Kumapley and Fricker (1996, p. 59) comment: "Estimates of vehicle miles traveled (VMT) are used extensively in transportation planning for allocating resources, estimating vehicle emissions, computing energy consumption, and assessing traffic impact." One method, used in the Netherlands, is based on panel data in which vehicle owners periodically report their odometer readings. This method can produce a reliable estimate of VMT provided that the sample is representative of the vehicle population. In the U.S., however, VMT is calculated by the states' Departments of Transportation, generally on the basis of traffic counts per network link.

Specifically, total VMT is annually reported by each state to the Federal Highway Administration. It is calculated by multiplying daily VMT times 365 days (366 days for leap years). Daily VMT is generally based on a product of the annual average daily traffic (AADT) on a given highway link and the centerline length of the corresponding link. AADT is generally obtained through counts of traffic on a given link over a 24- or 48-hour period, at one or more times of the year, with the results seasonally adjusted. All segments of interstate highways and other principal arterials are required to have new counts made at least once every three years (i.e. with at least a third of such segments sampled each year). In between new counts, AADT for a given segment is updated by applying estimated growth factors. AADT for the lower functional classifications (minor arterials and below) is generally based on counts taken on sampled segments. Some states estimate VMT for those functional classifications using fuel tax revenues (indicating how many gallons of fuel are sold) and data on fuel efficiency (miles per gallon) of the fleet.

It can be seen from this description that VMT estimates can have many sources of error: sampling (both of links and of days; Kumapley and Fricker, 1996), measurement (fallible counting devices, difficulty in determining what proportion of a mechanically-obtained count represents two-axle versus three-or-more-axle vehicles, inconsistent definitions between states), extrapolation to non-counted years, and so on.

Another example deals with safety measurement, commonly expressed in the number of fatalities per one hundred million passenger miles. Investment decisions are based, among other things, on the social costs of accidents associated with different modes of travel. However, data on fatalities connected with bus transit service in the U.S. ranges from 0.05 per one hundred

million passenger miles in 1997-1999 reported by the American Public Transit Association (APTA)[1] to 0.58 in 1975 (Altshuler, *et al.*, 1979). Theoretically bus safety might have dramatically improved since 1975, with fewer fatalities in the numerator being divided by a larger number of passenger miles in the denominator; however that is unlikely to fully account for such a sizable difference. Importantly, Altshuler distinguishes fatalities by bus occupants (0.07) and non-occupants (0.51). Since the figure for occupants is similar to the APTA figure, it is possible that APTA's figure also only involves passengers. While this might be logical from APTA's trade association perspective of marketing transit as a safe mode for its prospective passengers, it is obviously misleading without a more complete explanation.

To add to the confusion with respect to bus safety data, the U. S. Bureau of Transportation Statistics[2] reports in a single table for 1999, 58 fatalities involving "bus occupants (school, intercity, and transit)", and 91 "accident-related" fatalities for "transit buses". An unclear footnote associated with the latter figure may be interpreted to mean that it includes non-occupants as well as occupants. The corresponding number for occupants only cannot be obtained (since the first number combines urban transit with other forms of bus service). However, dividing the latter number by the 21,241,012,600 bus passenger-miles reported for fiscal year 2000 by APTA[3] gives 0.43 fatalities per hundred million passenger-miles – a number reasonably consistent with Altshuler's much earlier figure, and far higher than APTA's 1997-1999 average, offering further support to the speculation that APTA's number applies to occupants only.

As a final example from transportation, an impressive effort to measure and explain the impacts of automobile dependence was carried out by Newman and Kenworthy (1989). They initially collected data on numerous transportation, urban structure and population characteristics in 32 cities around the world, and at three points in time (1960, 1970 and 1980), which was later expanded to 46 cities and the year 1990 (Kenworthy, *et al.*, 1990). Armed with this data base, Kenworthy and his associates have performed a variety of analyses, showing, for example, the relationship between transportation energy consumption and urban density. Based on their results, they have advocated strong land use planning measures to maintain and increase urban densities in order to reduce energy consumption, and numerous academic and public policy documents (e.g. Ewing, 1997; UK Government, 1994) have drawn from their work for support of similar positions. Their research, however, has been subject to much criticism (e.g., Breheny, 1995, 1997; Brindle, 1994; Gomez-Ibanez, 1991; Gordon and Richardson, 1997), some of which relates to data quality as well as to the validity of their analysis methods, results, and policy implications. Although they have explained their data collection and standardization efforts with commendable thoroughness, it may be fundamentally impossible to obtain consistent definitions of a central business district or VMT for a cross-sectional sample.

3. BACKGROUND FOR THE CASE OF TELECOMMUTING

The mode of working known as telecommuting has enjoyed considerable growth since aerospace engineer Jack Nilles coined the phrase more than a quarter-century ago (e.g., Nilles, *et al.*, 1976). Perhaps facilitated by several high-profile public-sector demonstration projects in the late 1980s and early 1990s (SCAG, 1988; JALA Associates, 1990; Kitamura *et al.*, 1990; Quaid and Lagerberg, 1992; Ulberg, *et al.*, 1993), the adoption of telecommuting has apparently been

steadily increasing over the past two decades, even if not as rapidly as its enthusiasts may have predicted. The data discussed in this paper suggests that 10-12% of the workforce telecommuted at least once a month in 1998, with an average annual growth rate of 23% since 1988.

Telecommuting appears to have considerable popular appeal, offering employees the prospect of reduced commuting time, cost, and stress, more personal and/or family time, greater autonomy and ability to concentrate; and offering employers the potential of improved recruiting and retention, higher productivity, improved customer service (increased spatial and temporal reach), and savings on facilities costs. Several broad societal factors have combined to create a climate conducive to the adoption of telecommuting: "supply-side" factors include the increasing ubiquity, power, and ease of use of information and communications technology (ICT), the globalization of the economy, and the need for corporate cost-cutting as well as for obtaining highly-skilled workers; and "demand-side" factors include sociodemographic trends such as two-career households and the aging population, time pressures and congestion, and stress (Handy and Mokhtarian, 1996b; Salomon and Salomon, 1984).

In addition to benefiting employees and employers, telecommuting can potentially serve society at large in a number of ways as well. Perhaps the societal benefits most frequently mentioned are the reduction of peak-period congestion, fuel consumption, and criteria pollutants due to the decrease in commute travel. In the expectation of achieving those benefits, telecommuting in the U. S. has found its way into a number of public policy instruments, from regional transportation plans (SCAQMD and SCAG, 1989) and air quality regulations (SCAQMD, 1992), to state legislation (State of California, 1990; State of Florida, 1990; State of Washington, 1991; Gordon, 1992, 1993a, 1996; Castaneda, 1999) and Federal executive orders, laws, and programs (USDOT, 1990; Joice, 2000; Sec. 359 of H.R. 4475 (Wolf), Transportation Appropriations Act, signed into law October 23, 2000).

In addition to the congestion-reduction and related advantages, some prospective societal benefits claimed for telecommuting (e.g., Barr, 2001; Normann, 2000; Pratt, 1991; Sato and Spinks, 1998; USDOT, 1993; USDOE, 1994) include the employment of broader segments of the workforce and related economic development, strengthening families and local communities, reducing residential-area crime (through greater neighborhood monitoring by home-based workers), improving public health (through reduced exposure to traffic accidents and communicable diseases, as well as reduced stress), and offering a response to foreseen (e.g. the Olympics) or unforeseen major events affecting workplaces (e.g. the September 11, 2001 terrorist attacks on the World Trade Center and Pentagon, or a major fire or flood) or the transportation system (weather emergencies, earthquakes, major construction projects).

In view of the potential role of telecommuting as a "complex solution" (i.e., "a single intervention which is intended to solve many problems"; Salomon, 1998, p. 22), it would be desirable for public discourse about it to be based on a clear and common understanding of what it is and what trend it is taking. Instead, the lack of a concise and universally-accepted definition of telecommuting has confounded research and policy-making since the beginning. The use of inconsistent, unclear, or unsatisfactory definitions by different studies has resulted in a fundamental ambiguity with respect to the importance of the phenomenon. A number of attempts have been made to place telecommuting and its relatives within a typology of remote work options (Dick,

1996; Fritz, *et al.*, 1995; Helling and Mokhtarian, 2001; Huws, *et al.*, 1990; Kraut, 1988; Lamond, *et al*., 1997; Lindstrom, *et al*., 1997; Mokhtarian, 1991; Niles, 1994; Qvortrup, 1996; Salomon, 1990), yet we seem no closer to consensus than ever.

Perhaps such ambiguity is inevitable precisely because of the complex, multi-faceted nature of telecommuting as a social phenomenon, and because of the volatility of the technological, institutional, and social environment in which it is taking place. Perhaps the ambiguity (or, for that matter, the need for specificity) will diminish over time as it becomes more and more commonplace. In the meantime, however, it remains important for those studying the phenomenon, and those promoting it as sound public policy, to be clear about its boundaries in the context of interest.

This paper, then, is neither so bold nor so foolish as to attempt to achieve consensus with respect to the "best" definition of telecommuting. Rather, a key purpose is to identify some important issues to keep in mind when collecting and evaluating data on the phenomenon, and to apply those issues to the evaluation of currently available data on the amounts of telecommuting occurring in the U. S. Other valuable studies (e.g. Pratt, 2000, 2001, 2002) have also commented on definitional issues, analyzed telecommuting estimates based on various surveys, and offered advice on designing new surveys to measure telecommuting. The current paper does not focus on the design of new telecommuting surveys, but rather on the critical evaluation of existing data sources, offering our own original observations on the subject as well as synthesizing some of those expressed elsewhere. Nevertheless, the issues we raise in the context of appraising available data sources can be used to improve the design and reporting of future telecommuting data collection efforts as well.

4. THE IMPORTANCE OF CONTEXT

One reason for the numerous definitions of telecommuting – and a reason why consensus is unlikely – is that the "best" definition varies with the focus of interest. For example, if one's interest lies in assessing the demand for home office space and furniture (e.g., Melman, 1998), it would be important to focus on home-based workers (as opposed to mobile workers – "road warriors"), but whether a given worker were a salaried employee or self-employed may be less relevant, and a precise estimate of the number and timing of the hours spent working at home may also be less relevant. On the other hand, in assessing the demand for ICT equipment, identifying mobile workers (in addition to home-based workers) is extremely relevant. If one's interest lies in forecasting the spatial and temporal distribution of the demand for telecommunications services, then the location of the work, and even the times of day at which it takes place, becomes important.

The perspective taken in this paper is a focus on the transportation impacts of telecommuting. Specifically, the context is a time-series analysis of the impacts of telecommuting on vehicle-miles traveled at the nationwide level (Choo, *et al*., 2002a, b). This perspective drove two fundamental boundaries in the study. First, it motivated the choice of the word (and the focus on) "telecommuting" as opposed to "teleworking". At the broadest extreme, telecommuting is sometimes used interchangeably with teleworking to refer to *using information and communications technology to perform work "at a distance"*. Clearly, this definition includes

many situations in which travel either is not affected (overtime work from home; home-based self-employment for which the alternative is not working at all; ordinary uses of fax, e-mail, and telephone to reach distant parties) or is actually facilitated (use of mobile phones and laptops to support work while traveling). Although we acknowledge the legitimate interest of some groups in focusing on the "work" aspect rather than the "commuting" aspect of the phenomenon, from the perspective of understanding the potential to reduce peak-period congestion, the definition of telecommuting should be narrower than that of teleworking in the broadest sense. Conversely, it can be quite confusing when a broad term such as teleworking is then given a more narrow definition, as in the context of legislation promoting the trip reduction aspects of telecommuting.

Second, it motivated a focus on salaried employees of an organization, referred to as telecommuters, rather than on all teleworkers. In particular, we distinguish telecommuters from self-employed home-based business workers. Telecommuters are assumed essentially to eliminate (or greatly reduce, if teleworking at a location other than home) the commute on days that they telecommute, although this is a simplification, since some research (Mokhtarian, 1998) suggests that about 6% of telecommuting occasions may still involve the normal commute (i.e. that telecommuting is only partial-day in those cases). For home-based business workers, on the other hand, the impact on transportation is not clear, since it is unknown what the alternative to the home-based business would be in each case. For many people the alternative is presumably a conventional job with a conventional commute, but for many others the alternative may be a part-time job or no job at all, in which case the commute "reduction" due to working at home is lower or non-existent. In fact, at least one study (Mokhtarian and Henderson, 1998) found that home-based business workers in California had a daily mean drive alone travel time one-third higher than home-based telecommuters (0.82 versus 0.62 hours), although not as high as conventional workers (1.14 hours).

Further, from a policy standpoint, home-based businesses have not been the subject of the same attention as telecommuters have been, presumably because self-employed workers already have (to a large extent) the flexibility in choosing work times and locations that salaried employees are seeking to achieve through telecommuting.

In view of the ambiguity of the transportation impacts of home-based work, we focus only on conventional telecommuting here. However, home-based work is subject to many of the same measurement difficulties, and obtaining reliable data on its nature and extent is challenging (see, e.g., Pratt and Davis, 1985; Pratt, 1997). The available evidence indicates that home-based businesses enabled by ICT are a growing segment of the workforce. Although their numbers currently appear to be smaller than those of salaried telecommuters, they work at home more often. Thus, we believe that home-based business workers merit the same careful analysis that salaried telecommuters do.

In this paper, then, we treat *telecommuting* as *that subset of teleworking in which salaried employees of an organization replace or modify the commute by working at home or a location closer to home than the regular workplace, generally using ICT to support productivity and communication with the supervisor, co-workers, clients, and other colleagues*. We do not consider after-hours work to be telecommuting, if the employee still spends a full day at the regular workplace. We discuss the gray area of contract workers in Section 5.1.

In the context of studying the impact of telecommuting on transportation (or, for that matter, many other kinds of impacts, such as household interpersonal dynamics, or telecommunications demand), two measurement issues are important. First, it is naturally important to count the number of telecommuters, by whatever definition is used. But second, it is clearly important to know the frequency or extent to which telecommuting is occurring, not just the number of people doing it at all, no matter how infrequently. Sections 5 and 6 treat each of these issues in turn.

5. HOW MANY TELECOMMUTERS ARE THERE?

A number of organizations have produced estimates of the amount of telecommuting or home-based work in the U. S. from time to time. As indicated in the previous sections, the emphasis in this paper is on evaluating those existing U. S. data sources with respect to their usefulness and reliability for assessing the amount of telecommuting, especially from a transportation perspective. At least three dimensions are important to that evaluation: definition, quality, and quantity. In this section, we address key issues associated with each of these dimensions in turn, and then assess the available data in view of those issues.

Most of the sources measuring telecommuting at the aggregate level focus on home-based telecommuting. This is not a major concern, since center-based telecommuters in the U. S. probably number only in the hundreds (Stanek and Mokhtarian, 1998). Thus, the discussion below will be restricted to home-based work.

5.1 Who is a Telecommuter?

In evaluating sources measuring the amount of home-based work, the first question that arises is, "Who is being counted?" That is, "How is telecommuting [or whatever term is used] defined in this study?" This question actually contains several others:

- **What kind of worker is being counted?** If the types of occupations being measured are not restricted, counts of home-based workers will include farm workers, live-in domestic workers, and self-employed service workers in occupations such as child care, plumbing, and so on. It would perhaps be appropriate to restrict the count to information workers, but even non-information workers can legitimately telecommute – replace a commute trip – to some extent (Mokhtarian, 1998), and therefore categorizing each occupation as representing information work or not is far from straightforward.

- **What is the threshold frequency for being counted?** Obviously, there will appear to be a lot more telecommuters if the criterion is telecommuting "at least once a month", than if the criterion is doing it "at least three days a week".

- **What other criteria are applied?** Some surveys try to screen out inappropriate respondents (e.g., homemakers or uncompensated employees of a family business) by asking if they conduct "paid work at home". This can have several problems:

- The “paid work” may be a moonlighting job, undertaken in addition to a regular job involving commuting. In that case it would be erroneous to consider the respondent a telecommuter.

- A respondent may interpret the question as referring to being paid explicitly and directly for work done specifically at home. As a professional being paid a fixed salary rather than an hourly wage, she may not consider work at home to be “paid work” *per se* and hence erroneously not be counted as a telecommuter (Pratt, 2000). Deming (1994) distinguished between working at home “for pay” (including salaried telecommuters as well as self-employed home workers), and “taking work home” which he classified as “unpaid”. It is likely that many respondents to a question about working at home for pay would not make that distinction unless it is carefully drawn for them.

  In commenting on definitional differences between its 1986 and 1987 National Work-at-Home Surveys, the LINK Resources (undated, p. iv) marketing research firm remarked that, "In summary, self-employed homeworkers and home business operators probably tended to respond more to the 1986 phrase: 'income-producing work-at-home', while corporate homeworkers probably tended to respond more to the 1987 phrase, 'job-related work-at-home'. Thus, the balance between self-employed and corporate homeworkers shifted significantly toward the latter in 1987, more so than would be projected from the 1986 base data."

- On the other hand, if a salaried professional *does* consider his work at home to be “paid work”, but only works *overtime* at home without eliminating any commute trips, he could be erroneously *counted* as a telecommuter.

Another criterion sometimes applied is to ask whether the individual works at home under a “formal arrangement” with the employer. This screen seems likely to miss the considerable amount of irregular and ad hoc telecommuting that occurs, and even many regular telecommuters may not consider themselves to have a formal arrangement (Dannhauser, 1999; for example, there may be nothing in writing indicating such an arrangement, no prior training, no special reporting requirements).

A final important definitional question to ask is:

- **What forms of employment are being counted?** Specifically, does the count include home-based business workers, salaried employees, or both? As discussed in Section 4, the transportation impacts of home-based business workers are more ambiguous than those of salaried employees who telecommute. An additional complication is the prevalence of multiple job holding or moonlighting. Unless the questions about working at home are carefully worded, moonlighters could be classified as telecommuters (since they were initially identified as salaried), but erroneously so if most of their work at home is conducted for a home-based business rather than as a salaried employee.

  Some surveys include additional categories, such as contract workers. The latter may be employees of a staffing or temp agency, or may be technically self-employed, but have a

long-term arrangement with one or a small number of clients for whom they may act almost as an employee (Pratt, 2000). Given the transportation context of the present study, we include contract workers among the count of telecommuters, in the belief that contract workers are more similar to salaried employees than to independently self-employed workers in their commute and other travel patterns.

5.2 Quality and Quantity of Telecommuting Data

Aside from the central question of how telecommuting is defined, it is also important to consider the quality and quantity of data available from a given source. With respect to *quality*, some questions to ask are:

- **On what size sample are the numbers based?** All else equal, a larger sample produces more precise estimates of the characteristic of interest than does a smaller sample. In a survey of home-based work, it is sometimes not clear if the reported sample size is based on the entire sample of conventional as well as home-based workers, from which the proportion of home-based workers can be estimated, or whether it represents the number of home-based workers in the sample. In the former situation, clearly the number of home-based workers will be considerably smaller than the reported sample size, which means that the estimates of *characteristics of home-based workers* will be less precise than the published full sample size would suggest.

- **Was the sample properly drawn and weighted to be representative of the population?** On the other hand, unless the sample is properly handled, even a very large sample can be unrepresentative of the population of interest, and therefore inferior to a smaller sample that *is* representative. Unfortunately, the procedures by which the sample was drawn and weighted are seldom presented in publicized summaries of the results, and thus it can be difficult to judge the reliability of the sample. The fact that organizations that collect statistics on a regular basis frequently report revised estimates a year or two later is evidence that, for example, the proper weighting for a sample can be open to judgment and capable of improvement. Such practices leave one wondering whether estimates that remain unrevised do so because they are "right" (or as "right" as they can be made) – or only because they haven't been as carefully examined as those that *are* revised.

- **Could the results have been influenced by internal or external considerations?** The individuals who are counting home-based workers are human beings living in a social context for their work, not completely impartial machines performing a neutral and exact calculation. As such, all humans bring an element of subjectivity to the task at hand. Even something as elemental as the analyst's personality – e.g. whether she is an optimist or a pessimist – may affect how she approaches the problem and interprets the results. In the current context, there may be a number of forces at work to bias upward the published forecasts of telecommuting (Salomon, 1998). It should be emphasized that the effect of these forces on any given individual may be conscious or unconscious:

    - Widely-publicized statements of key opinion leaders have predicted major increases in remote work, and it can be difficult to "buck the current". For example, management

expert Peter Drucker claimed in 1989 that "[i]n 20 years Japanese office workers may still commute … to downtown office towers. But no one else in the developed world will… [C]ommuting to office work is obsolete" (Drucker, 1989, p. 38)[4]. More recently, the senior and respected statistician Norman H. Nie predicted that, "by 2005, at least 25 percent of the American workforce will be telecommuters or home office workers" (1999, p. 50).

- When putatively neutral government agencies include predictions of major increases in their reports (e.g., USDOE, 1994), it may invest those predictions (sometimes made by other interested parties) with greater weight.

- When the same numbers or predictions (whether quantitative or qualitative) are repeatedly cited in a variety of contexts, they take on the aura of "conventional wisdom" and tend to be accepted more and more readily.

- Often the predictions are made or sponsored by a party with a vested interest in promulgating a higher number. Such predictions are not wrong simply because of that fact, but they should be viewed with considerable caution.

- The media are oriented toward reporting unusual events or novel ideas rather than the typical, and so they are likely to invest evidence of a new trend with greater weight than is warranted.[5]

- On the other hand, there is a natural tendency to rely heavily on personal experience and anecdotal information in interpreting data, and to project that perspective onto the population as a whole. Thus, reporters and academics, whose jobs naturally lend themselves to working remotely and from multiple locations, may be more inclined than a "typical" worker to see telecommuting as becoming the norm.

- Technological determinism, the belief that technology can be counted on to solve societal problems, often leads to overoptimistic projections of the adoption or impacts of technological innovations (Ferguson, 1986; Kraut, 1987). This syndrome is certainly represented among some of the proponents of telecommuting as a solution.

- **Are the results plausible?** One way to help counter the inevitable lack of objectivity discussed above is to subject results to a separate reality check. If a certain result has logical implications that are not credible, then clearly the legitimacy of the result is open to question.

With respect to *quantity*, in addition to the sample size question raised above, another relevant question is simply:

- **For how many years are comparable counts available?** For a study such as ours (Choo, *et al.*, 2002b), involving a time series analysis, it was important to have a series of data for as many years as possible, with the variable of interest defined consistently across time.

5.3 Evaluation of Available Sources

Five different sources of published data on the number of home-based workers in the US were identified for this study.[6] Table 1 summarizes the important information about each source. The source labeled "market research firms" refers to a series of annual surveys of home-based work directed by a single individual, Thomas E. Miller, under the auspices of several different firms over time: LINK Resources, FIND/SVP, and Cyber Dialogue.

[Table 1 goes about here]

One immediate observation from the table is the disparity in definitions of what is being counted by each source. This doubtless contributes to the wide range of numbers for years in which there is more than one estimate. Consider, for example, the four different estimates available for 1997:

- 5.0 million salaried employees by the Survey of Income and Program Participation (SIPP) of the U. S. Census;
- 5.5 million wage/salary employees by the American Housing Survey (AHS);
- 3.6 million wage and salary workers by the Bureau of Labor Statistics (based on the Current Population Survey, CPS); and
- 11.1 million telecommuters by the market research firm of FIND/SVP.

But the CPS data counted only "formal arrangements" of home-based wage and salary work, which as indicated above is likely to undercount the number of telecommuters. The SIPP counted only those who worked *only* at home, at least one day of a typical week the previous month. Both conditions are likely to undercount the number of telecommuters (by excluding partial-day and less frequent telecommuters), although the focus on a "typical" week rather than the previous week will tend to inflate the numbers. Similarly, the AHS number includes only those working at home for at least one day the previous week *instead of traveling to work* – a definition relatively close to that of the SIPP, and hence it is reassuring to find those two numbers roughly equal. On the other hand, the FIND/SVP survey included contract workers as well as salaried employees in its total. Excluding the 3.4 million reported contract workers from that total (leaving 7.7 million salaried telecommuters) and hypothetically inflating the CPS number to correct for a downward bias would bring all four counts closer together, although discrepancies would still remain.

Key issues associated with each source can be briefly summarized as follows:

US Census Bureau: The decennial census counts only those who worked at home most of the preceding week, so it undercounts telecommuters by excluding those who do so less than three days a week (for a discussion of the proportion of telecommuters for which that is true, see Section 6 below). On the other hand, it includes farm, domestic, and service workers whose home-based work does not replace a commute, so in that respect it is an overcount (Handy and Mokhtarian, 1995; Pratt, 2000). The net effect of these two counteracting biases is uncertain (although various occupations can be screened out in a specialized analysis of the Census data). In any case, full Census data are available only for decennial years, which further limits its suitability for many studies. It is interesting, however, that the proportion of the employed labor

force working at home by this definition stands at 3% in both 1990 and 2000, suggesting that this segment of home-based work is not increasing beyond the normal growth in the population.

As indicated above, the ongoing Survey of Income and Program Participation[7] counted those who worked *only* at home at least one day of a typical week in the previous month, and hence probably undercounts the number of telecommuters.

American Housing Survey: The AHS counted people working at home in a number of different categories, but we focus here on the one of particular interest to a study of transportation impacts: the number of people working at home instead of traveling to work. As mentioned above, this counted people working at home at least one day of the preceding week instead of traveling to work, which probably undercounts the total number of telecommuters. (Excluding those who worked at home but also commuted is desirable from the standpoint of evaluating the reduction in vehicle-miles traveled, but excluding less frequent telecommuters is not necessarily desirable, since many people are likely to telecommute relatively casually). Although asking about "working at home instead of traveling to work" is perhaps the clearest way the commute reduction impacts can be identified, even that wording is subject to misinterpretation. Some self-employed individuals may include themselves in this category, on the premise that if they weren't self-employed they would normally be commuting to a salaried job. Potentially, some multiple job-holders may include themselves here if they stayed home from their primary salaried job in order to work at their second job, or chose to regularly work part-time at their primary job in order to engage in a home-based second job. As noted in Section 6, apparently 96% of the 5.7 million people counted under this definition in 1997 were salaried employees (although some or all of the remainder could have been contract workers), and 47% were self-employed (indicating substantial multiple job holding).

Interestingly, using the same definitions the AHS counted slightly fewer people (5.6 million) telecommuting in 1999 than in 1997 (5.7 million; Pratt, 2002).

Current Population Survey (CPS) of the Bureau of Labor Statistics (BLS): As mentioned above, this source probably undercounts telecommuters by focusing on those with "formal arrangements". Nie (1999, p. 50) says that the 1997 estimate "is likely to be low by as much as 1 million, because of the ambiguity of their telecommuting question." BLS also publishes counts of wage and salaried employees working at home, which of course are higher than the counts of wage/salaried employees with formal arrangements working at home for pay, but the difference is largely due to overtime work done at home, which is not of interest in the context of evaluating transportation impacts.

It is again interesting that the number of telecommuters counted by the same definition declined slightly in 2001 (3.4 million) compared to 1997 (3.6 million).

Market research firms: This represents the longest series of data on number of telecommuters, with estimates available each year between 1988 and 1998. The estimates are based on 2,000 – 2,500 randomly-selected households interviewed by telephone each year. Individual observations are presumably weighted to reflect national distributions on key variables.

There are several concerns with the market research data:

- Since telecommuters represent a relatively small proportion of the total work-at-home population (other segments measured in the same survey include self-employed home workers, moonlighters, and those who only do overtime work at home), the projected number of telecommuters in the population is based on numbers much smaller than the total sample sizes in these studies. For example, the estimate of 5.5 million telecommuters in 1991 is projected from a sample of 176 telecommuters (personal communication of Tom Miller to P. L. Mokhtarian, 7/15/1991). Even the larger projections in later years must have been based on samples of around 200 or so. Estimating the population proportion of telecommuters from the sample proportion out of a total of 2,000 households can theoretically be done with a reasonable degree of accuracy. But that is true only under the assumption that the sample is properly weighted. As discussed above, this is by no means a cut-and-dried process, and there is much room for error. For example, FIND/SVP originally publicized the number of telecommuters in 1996 as 8.7 million, and later revised its estimate upward to 9.7 million. Smaller corrections were also made to the numbers initially disseminated for 1990, 1993, and 1995 (see notes on Table 1).

- Moonlighters are theoretically counted in a separate category ("part-time self-employed homeworkers"). But, in a personal communication to Susan Handy (3/8/1993), Mr. Miller reported that among the 4.19 million conventional employees counted as telecommuters in 1992, 1.83 million (44%) were moonlighters. This raises the question as to whether some people in this category were incorrectly classified as telecommuters when in fact all their home-based work was conducted for their second job.

- The number of telecommuters estimated for 1998 was placed at 15.7 million. A press release on Cyber Dialogue's web site comments that this number comprises 7.4 million full-time employees, 4.0 million contract-based workers, and 4.3 million "part-time employees who telecommute informally". The latter segment was found to contain mostly "retirees and homemakers who are capitalizing on the full-employment economy to supplement income via home-based work. Almost three out of four of this segment are women, by far the highest ratio of the three telecommuting segments. This group was found to be very low-tech and much more a reflection of the strong economy than of PC and Internet adoption." It seems clear, then, that this segment of part-time informal telecommuters is for the most part not going to be reducing commute travel: the alternative for most of them is not "working at a conventional job", but rather "not working at all". We considered eliminating this group from the total, but ultimately decided not to do so because previous years' totals for conventional employees also included both full- and part-time employees without distinguishing them – and so eliminating part-time employees from the 1998 total only would have been inconsistent.

Telework America: The trade association International Telework Association and Council (ITAC) sponsored surveys of teleworking during "Telework America" (TWA) promotional weeks in 1999, 2000, and 2001. The surveys were conducted by different parties and differed in sampling procedure and definition of a telecommuter (see notes on Table 1). Because of these distinctions, it is difficult to compare the three numbers.

The estimated number of telecommuters for 1999 was 19.6 million (employees and independent contractors). It is not entirely clear why this number is so much higher than others for the same and nearby years. The survey director speculates that it may be due to the inclusion of multiple job holders whose home-based work is primarily for their second job (personal communication of J. H. Pratt to P. L. Mokhtarian, 8/16/2002).

The number of telecommuters estimated for TWA in 2000 (10.3 million) counted only the "regularly employed", and is much lower than the 1999 number – lower even than the 1997 and 1998 numbers (11.1[8] and 15.7 million) in the market research series. Further, using screens consistent with the year 2000 survey, the number of telecommuters in 2001 is estimated by us to be 10 - 12 million (see notes on Table 1). Placing the 2000 and 2001 TWA numbers in sequence with the market research series, and remembering that a more valid number for the 1998 Cyber Dialogue study would be 11.4 million (excluding the 4.3 million part-time informal telecommuters who were largely retirees and homemakers), suggests that the number of telecommuters has been fluctuating around 10-11 million for the five years 1997-2001. This observation, combined with the slight declines (or, relative stability) previously noted for the four AHS and CPS counts taken between 1997 and 2001, raises the question of whether that degree of penetration of telecommuting might constitute an equilibrium; at a minimum it suggests that telecommuting might be growing much more slowly now than in years past. Pratt (2002) raises a similar question, using different definitions for various forms of telework.

The conclusion from the above discussion is that none of these sources is entirely satisfactory, for various reasons. Ultimately, the necessity of having data measured reasonably consistently over a series of years dictated the choice of the market research series of numbers for our particular study. However, it should be stressed that these numbers, based as they are on small samples that must rely on the proper weighting in order to be representative, are in our opinion subject to a great deal of uncertainty. For one thing, although available information is sketchy, the definitions used in the surveys do appear to have evolved over the years (Gordon, 1998). Overall, the impression given by the concerns outlined above is that these data are likely to overcount the number of "true" telecommuters – those who will genuinely be reducing commute travel. Nie (1999, p. 50) also shares the belief that at least the 1998 estimate is "arguably too high because of their sampling methodology", although he does not elaborate.

To some extent it can be argued that when a trend analysis is the focus of study, errors in the absolute numbers are not so important, since errors operating in the same direction will tend to cancel out when assessing the change in telecommuting from year to year. On the other hand, for studies such as our time series analysis of the impacts of telecommuting on vehicle-miles traveled (VMT), if absolute numbers of telecommuters are overstated, it is possible that the true numbers of telecommuters would not be high enough to create a measurable impact on VMT, or that such an impact, even if measurable, would be harder to detect amidst the "noise" in the data.

6. HOW OFTEN DO THEY TELECOMMUTE?

So far, the discussion of measuring the amount of telecommuting has focused on the number of telecommuters. But Handy and Mokhtarian (1995) distinguish between telecommuting *penetration*, and *level*. Penetration refers to the number of people who have adopted telecommuting, whereas level refers to the number of telecommuting occasions against some reference (such as number per day or per week, or percent of person-workdays on which telecommuting occurs). As indicated in Section 4, from the standpoint of understanding the impacts of telecommuting on distance traveled (among others), it is important to assess not only the penetration of telecommuting (how many are doing it), but also its level or intensity (how often it is being done).

Data on the frequency of telecommuting are even less available than data on the number of telecommuters, and when they are available, they are subject to many of the same issues discussed with respect to number of telecommuters. In addition, data on telecommuting intensity, so to speak, are often gathered and/or presented in the form of number of hours per week that are worked at home. The translation of that form to number of commute trips eliminated is ambiguous. For example, if a telecommuter reports working 16 hours a week at home on average, that could constitute:

- two full 8-hour days for which the commute was eliminated;
- one 8-10-hour day for which the commute was eliminated, plus 6-8 hours of overtime work on days involving a normal commute and/or weekends;
- four days on which the individual worked at home for half the day but still made the commute (with one direction in the off-peak);
- 5-6 days on which the individual worked at home in the evenings after making the normal peak-period commute all five weekdays;

or any number of gradations in between (personal communication from T. E. Miller to P. L. Mokhtarian, 7/15/1991). Obviously the impacts on VMT and peak-period VMT vary widely among these alternatives. A further complication is that telecommuting often results in a rearrangement of the work schedule to suit personal needs, so that work on a telecommuting day may not occur during the conventional 8 a.m. – 5 p.m. window. Thus, when surveys report the proportion of time that a telecommuter works outside "normal working hours", it is not clear how much of that is replacing time in the regular office and how much is overtime supplementing a full day in the office.

The press releases and other reports associated with the marketing research numbers adopted for our time series study provide some information about telecommuting frequency, for several but not all of the years in the series. This information is generally in the form of average number of hours per week worked at home. This average ranges between 16.5 and 19, as reported for four of the 11 years in the series, with a frequency of 7-8 days/month (which translates to 1.6 – 1.8 days/week) reported for a fifth year. Importantly, for one year (1997), it was reported that the average hours per week worked at home was 18-19, with a median of 12. Thus, typical frequencies are lower than the arithmetic average suggests, which is skewed upward by a small proportion of very high frequency telecommuters.

To be included in the count for the marketing research studies, telecommuters needed to "work at home during normal business hours", at least one day a month. We can probably assume that one *full* day a month is meant (i.e. that for at least one day a month, the worker does not commute to the office at all). We generally know nothing beyond that about the number of days over which an average weekly number of hours of home-based work is spread, nor how many of those days (1) eliminate the commute altogether (full day telecommuting); (2) shift one or both legs of the commute out of the peak (partial day telecommuting); or (3) do not affect the commute at all (overtime work at home). However, more information is available for one year. In 1995 (FIND/SVP, 1995), it was reported that "employee brings work home after hours" an average of 39.6 hours per month, while "employee telecommutes" 39.5 hours per month. With an average of 4.3 weeks per month, this suggests an average of 9 hours per week – one day a week or slightly more – spent in actual telecommuting, with a similar amount spent on after-hours work. This may be a typical result for the other years in which totals of 16.5 - 19 hours per week worked at home are reported.

The CPS surveys also collected data on hours per week worked at home. For the 3.6 million wage and salary workers doing paid work at home related to their primary job in 1997, the mean number of hours per week usually worked at home was reported to be 14.9 (ftp://ftp.bls.gov/pub/news.release/History/homey.031198.news, accessed 8/23/2002). For the 3.4 million wage and salary workers doing paid work at home related to their primary job in 2001, the mean number of hours per week usually worked at home was reported to be 18.0 (http://www.bls.gov/news.release/homey.nr0.htm, accessed 7/30/2002)[9]. Although translating hours per week to days per week is problematic as discussed above, the consistency of these numbers with those reported by the market research studies suggests a certain amount of robustness in this measure of telecommuting intensity.

A number of studies in the academic literature estimate average telecommuting frequencies in days per week that are similar to the 1995 market research result. For example, Handy and Mokhtarian (1995) reported an average of 1.2 days per week, across eight different studies. Additional sources cited in Mokhtarian (1998) report average frequencies ranging between 0.9 and 1.4 days per week. Since the dates of these studies range from the late 1980s to mid-1990s, and include programs in the Netherlands and Australia as well as the US, they suggest a fair amount of spatial and temporal stability in typical telecommuting frequencies. One could reasonably hypothesize changes in either direction over time (Handy and Mokhtarian, 1996a). On the one hand, the early adopters of telecommuting studied in the literature may be more enthusiastic about telecommuting than the mainstream and thus average frequencies would decline as telecommuting spread. On the other hand, technological improvements and increased managerial acceptance may allow people to telecommute more often as time goes on. Both of these effects could occur simultaneously, and counteract each other to unknown degrees.

Sources for the SIPP and AHS surveys discussed in Section 5 also contain some information on frequency. Table 2 presents the distribution of days worked at home for various categories of people measured by those two surveys. Both surveys imply considerably higher average frequencies of home-based work than the other evidence presented above, but in neither case is the evidence clear-cut.

[Table 2 goes about here]

The 1997 SIPP survey found an average of 1.8 days a week (out of 5.2 on average) worked at home for "mixed" workers (those who did not work only at home) and 4.9 days per week for "home" workers (those who worked only[10] at home); 3.9 days per week overall. However, both the mixed and the home categories include self-employed as well as salaried workers, whereas to be comparable with the other estimates presented above, we should look only at salaried workers. Kuenzi and Reschovsky (2001) report that 1.034 million (36%) of the mixed workers and 3.190 million (50%) of the home workers were self-employed in 1997, but do not provide enough information to separate the frequency distributions appropriately. A simple weighted average of the averages yields an estimate of 3.8 days a week[11] worked at home for the salaried workers, but that relies on the assumption that the frequency distribution of salaried mixed workers is the same as that of self-employed mixed workers, and similarly for home workers. To the contrary, it is likely that salaried workers are more concentrated among the lower frequencies and self-employed workers are more often found at higher frequencies.

The lowest possible average frequency for salaried workers that is consistent with the SIPP data can be obtained by assuming that the 1.034 million self-employed mixed workers entirely occupy the higher frequency categories of Table 2, and that the 3.195 million salaried home workers all occupy the lower categories. This yields a lower-bound telecommuting frequency for salaried workers of 2.9 days a week. In trying to reconcile these numbers with the lower ones found in the many studies mentioned above, several observations can be made:

- The emphasis on a "typical" week is likely to inflate reported frequencies. Respondents may tend to report a desired or target frequency, which some studies (e.g., Mokhtarian, *et al*., 1997; Varma, *et al*., 1998) have shown to be higher than the actual frequency. So, for example, if an individual wants and tries to telecommute two days a week, but misses one of those days about half the time, he may report his frequency in a typical week as two days, when the actual average would be 1.5 days.

- By design, the sample on which these numbers are based was biased toward higher frequencies, by excluding people who worked only from home less than one day in the typical week. As such, it is inevitable that telecommuting frequencies will be higher in this case than for samples with a once/month threshold, such as the market research surveys.

- Table 3 of Kuenzi and Reschovsky (2001) classifies workers as self-employed, "yes" or "no". It is not stated whether this classification is based on the primary job or not. If the distinction was not clarified to the respondent, the self-employed category may include a number of moonlighters who would more properly be considered salaried.

- To be counted, the individual must have worked only at home at least one day in a typical week, but it is not clear whether *all* days worked at home in Table 2 were *only* worked at home. If days of working partially at home (perhaps only overtime), and partially at the main office are included, the actual frequencies of commute-eliminating telecommuting could be

quite consistent with those mentioned above, which excluded overtime work at home and included relatively little partial-day telecommuting.

- On the other hand, if all days in Table 2 *were* "only" worked at home, then the SIPP total column shows that 5.71 million people, or 4.3% of the workforce, worked at home 4 or more days a week. This is a considerably higher proportion than for the 2000 decennial census, which is difficult to explain.

The AHS survey is similarly biased toward more frequent (once-a-week or more) telecommuters, and averages of 3.3-3.4 days a week worked at home are found for the 1995, 1997, and 1999 waves. In this case, Keil (2000) and the web source are clear that the distribution is for the number of days worked at home instead of traveling to work (i.e. that presumably each day represents an eliminated commute trip). But, focusing for example on the 1997 numbers, although 96.1% of the group (5.47 million) is presumably wage/salaried (since they worked at home at least one hour a week on a wage or salary job), 47.4% of the same group (2.70 million) worked at home at least one hour a week self-employed (similar proportions of 93% and 46%, respectively, apply to the 1999 data, as shown in Pratt, 2002). Thus a high proportion of the salaried workers in this group are also moonlighting as self-employed (or conversely), and there is likely to be some confounding of the two forms of work when a given respondent doing both reports on the number of days she works at home. It would be of interest to determine the frequency distribution only for the 5.47 million salaried workers who worked at home instead of commuting – disaggregated within that subgroup by those who also worked at home self-employed and those who did not.

As noted in Section 5.3, the 1997 telecommuting penetration estimates for the SIPP and AHS surveys were close to each other (5.0 and 5.5 million, respectively) and far lower than the market research estimate (11.1 million). We now see that the average telecommuting frequencies estimated by SIPP and AHS are considerably higher than those reported by the market research firm. To a great extent, these two sources of conflict will counteract each other: e.g. one could obtain 13.3 million weekly telecommuting occasions either from assuming 5.0 million people do it about 2.66 times a week each, or from assuming that 11.1 million do it about 1.2 times a week each. Nevertheless, it is obviously more desirable to be confident in each factor than to count on errors in opposite directions canceling out.

7. CONCLUSIONS

The analysis in this paper indicates that a great deal of uncertainty surrounds estimates of the number of telecommuters and frequency of telecommuting. It is clear that the answers obtained depend very much on the questions that are asked, and that framing the phenomenon of interest is central to framing the questions (see, e.g., Mokhtarian, 2003). Achieving consensus on the "best" definition of telecommuting (or any of its relatives such as teleworking) is unlikely, due to its multifaceted nature and the variety of perspectives from which people approach the subject. In view of that reality, it is imperative to critically scrutinize published numbers on the amount of telecommuting, to determine their suitability for an intended purpose. Understanding the definition of telecommuter used in the data collection is one paramount concern, but questions with respect to the quality and quantity of the data also need to be asked.

The imperfect evidence that is available suggests that telecommuting appears to be an important enough trend to justify the cost and effort required to collect reliable data with respect to its adoption and frequency, on an annual basis. It is hoped that the considerations discussed here will be useful to such an effort.

More generally, government agencies as well as non-governmental organizations that seek to develop and evaluate policies must be equipped with sufficient and relevant data. Each of these actors has to make what Churchman (1959) described as managerial decisions concerning measurement. Specifically, he referred to the choice of language of the measurement; the specification of what is measured; the standardization of the measurement, so that comparison can be made; and accuracy, to enable evaluation. In addition, there is a need to decide on the tradeoff between measurement accuracy and costs.

The magnitude of costs of a policy at hand (e.g., promoting telecommuting, building a new road in a metropolitan area, devising parking policies or improving rail systems), should be one major consideration with respect to how much data should be collected and how precise it should be. The description of telecommuting data problems presented here demonstrates the complexity involved in verifying the utility of data. Similar situations can be found in many other contexts, both within and outside the transportation field. The issues raised in this paper are intended to help researchers, policymakers, and the public be informed consumers of already-available data, but can also be taken as implicit advice with respect to the design and reporting of future data collection efforts – whether for telecommuting or in other areas of public policy analysis. Clearly, although *post hoc* attention to these issues is crucial, it is even more desirable to attend to them in the data collection design stage itself.

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Table 1: Summary of Data Sources for Number of Telecommuters

Data Source	Year	Count of Home Workers (millions)	Sample Size	Who Measured	Frequency Threshold	Nature of Arrange-ment	Form of Employment
US Census	1980	2.2 (2.3% of total emp.)	one in six US households	all workers 16 and over	most of previous week	any	salaried and self-employed
	1990	3.4 (3% of total emp.)					
	2000	3% of total emp.					
	1997 SIPP	9.3 (7% of total emp.)	32,925 interviews	civilian non-institu-tionalized population age 15 and over	worked *only* at home at least one day in a typical wk. of the previous mo.	any	salaried (5.0M) and self-employed (4.2M)
American Housing Survey	1995	4.8	61,000 dwelling units	household members age 16 and over	at least one day the previous week instead of commuting		
	1997	5.7		household members age 16 and over	at least one day the previous week instead of commuting		5.5M worked at home at least 1 hr. that week on a wage/salary job; 2.7M at least 1 hr. that week self-employed
	1999	5.6		household members age 16 and over	at least one day the previous week instead of commuting		5.2M worked at home at least 1 hr. that week on a wage/salary job; 2.6M at least 1 hr. that week self-employed
Current Population Survey	1991	1.9	~60,000 households	non-farm workers age 16 and over	none (30% worked at home 8 hrs/wk or more)	any	wage and salary
	1997	3.6	~50,000 households	non-farm workers age 16 and over		formal	wage and salary workers, doing some paid work at home for primary job
	2001	3.4	~60,000 households	non-farm workers age 16 and over	at least once/week	formal	wage and salary workers, doing some paid work at home for primary job

Table 1 (continued)

Data Source	Year	Count of Home Workers (millions)	Sample Size	Who Measured	Frequency Threshold	Nature of Arrange-ment	Form of Employment
Market Research Firms: LINK Resources	1988	2.2			none		company employees
LINK Resources	1989	3.0			none		salaried employees
LINK Resources	1990	4.0	2,500 total households		none		company employees
LINK Resources	1991	5.5	2,500 total households, 176 total telecommuters	all occupations (assumed)	none		company employees
LINK Resources	1992	6.6	2,500 total households	all occupations (assumed)	none	formal (3.1M), informal (3.5M)	company employees, including "conven-tional" (4.2M) and "contract-based" (2.4M)
LINK Resources	1993	7.3	2,500 total households		none		"pure corporate telecommuters" (5.12M) plus contract workers
FIND/SVP	1994	9.1	2,000 total households		at least one day/month		corporate (6.6M) and contract workers (2.6M)
FIND/SVP	1995	8.5	1,200 total households		at least one day/month		conventional employees (5.4M) and contract workers (3.1M)
FIND/SVP	1996	9.7					conventional employees (6.5M) and contract workers (3.2M)
FIND/SVP	1997	11.1	2,000 total households		at least one day/month		conventional employees (7.7M) and contract workers (3.4M)

Table 1 (continued)

Data Source	Year	Count of Home Workers (millions)	Sample Size	Who Measured	Frequency Threshold	Nature of Arrange-ment	Form of Employment
Cyber Dialogue	1998	15.7	2,000 Americans age 18 and older	all occupations (assumed)	at least one day/month	NR	full-time employees (7.4M), part-time employees (4.3 M), and contract workers (4.0M)
Cyber Dialogue	2000	16.3		all occupations (assumed)	at least one day/month	NR	
Telework America	1999	19.6	2,711 surveys; 247 tele-workers	18 years or older, head of household, all occupations	at least one day/month		employees (78%) and independent contractors (22%)
	2000	10.3	1,877 households	18 years or older, all occupations (assumed), regularly employed home-based teleworkers	at least one day/month		employees (8.3M) and contract workers (2.0M)
	2001	18.5	1,170 households				"employees" (salaried, contract, and self-employed not distinguished)

Notes for Table 1 (blanks in main table mean no information available)

Data Source	Year	Information Sources	Notes
US Census	1980	Deming (1994)	
	1990	Deming (1994)	
	2000	*USA Today*, 8/6/2001	
	1997	Kuenzi and Reschovsky (2001); personal communication of Earl Letourneau, earl.j.letourneau@census.gov, to the first author, 3/6/2002	Survey of Income and Program Participation (SIPP). Sample size obtained from Letourneau. The breakdown by form of employment was calculated from Table 3 of Kuenzi and Reschovsky, where "not self-employed" is assumed to mean "salaried". According to Letourneau, the self-employed category does not include contract workers, and so they are assumed to be included under salaried. The 1995 SIPP identified 10.9M home-workers, but the 1997 survey focused more clearly on work at home for the primary job, and so the two sets of numbers may not be directly comparable.

Notes for Table 1 (continued)

Data Source	Year	Information Sources	Notes
American Housing Survey	1995	Keil (2000), Pratt (1997)	
	1997	Keil (2000)	
	1999	Pratt (2002)	
Current Population Survey	1991	Deming (1994)	
	1997	Dannhauser (1999), Mariani (2000), ftp://ftp.bls.gov/pub/news.release/History/homey.031198.news, accessed 8/23/2002	Figure reported is "the number of wage-and-salary employees who said they did some telecommuting from home [for their primary job] and got paid for it" (Dannhauser, p. 53).
	2001	http://www.bls.gov/news.release/homey.nr0.htm, accessed 7/30/2002	"At least once a week" is referred to as "usually". Question wording: "Do you have a formal arrangement with your employer to be paid for the work you do at home, or were you just taking work home from the job? 1. Paid 2. Taking work home"
Market Research Firms: LINK Resources	1988	Braus (1993), "1991 Telecommuting Data from LINK Resources Corporation" (June 1991)	
LINK Resources	1989	Gordon (1990), "1991 Telecommuting Data from LINK Resources Corporation" (June 1991)	Telecommuters defined as "salaried employees doing work at home during normal business hours".
LINK Resources	1990	Braus (1993), Gordon (1990), "1991 Tele-commuting Data from LINK Resources Corporation" (June 1991)	Telecommuters defined as "salaried employees doing work at home during normal business hours". 3.6M in 1990 source changed to "4.0 million" in 1991 source.
LINK Resources	1991	Gordon (1991), *Urban Transportation Monitor* (1991), undated press release from LINK Resources received 7/15/1991, personal communication from T. Miller to P. L. Mokhtarian, 7/15/1991	Telecommuters defined as "company employees who work at home part- or full-time during normal business hours". Press release indicates 43% of telecommuters are in professional and executive occupations; "nearly one-fourth are in a variety of manual and low-tech jobs".
LINK Resources	1992	LINK Resources "1992 Home Office Fact Sheet"; personal communication from Thomas Miller to S. L. Handy, 3/8/93	Telecommuters defined as "company employees who work from home part- or full-time during normal business hours". Includes "contract-based" workers as well as "conventional employees". Of the 4.2M conventional employees, 1.83M moonlight and 2.36M do not.
LINK Resources	1993	Gordon (1993b, c); USDOT (2000)	Gordon (1993b) reported 7.5M; adjusted to 7.6M in Gordon (1993c); reported as 7.3M in USDOT (2000, p. 6).

Notes for Table 1 (continued)

Data Source	Year	Information Sources	Notes
FIND/SVP	1994	FIND/SVP (1995), Russell (1996), presentation made by Thomas Miller to Telecommute '94 conference, San Francisco, Oct. 25-27.	Sample size mentioned in 12/7/95 audioconference cited below.
FIND/SVP	1995	July 21, 1997 press release on etrg.findsvp.com/prls/pr97/telecomm.html, accessed 7/21/97; audioconference presentation of T. Miller to Telecommuting Advisory Council, 12/7/95	Telecommuters defined as those working for an outside employer but working at home during normal business hours at least one day/month. Commented that the frequency screen of one day/month was added in the last two years, but that the rest of the definition has been consistent throughout. Number of telecommuters placed at 8.1M in 12/7/95 audioconference; later updated to 8.5M.
FIND/SVP	1996	USDOT (2000); July 21, 1997 press release on etrg.findsvp.com/prls/pr97/telecomm.html, accessed 7/21/97	Number of telecommuters in 1996 originally placed at 8.7M (USDOT, 2000). In 1997, this number was revised to 9.7M. A later FIND/SVP document reporting on the 11.1M telecommuters estimated for 1997 (etrg.findsvp.com/prls/pr97/telecom.html, accessed 1/20/98) commented, "Only 8.5 million telecommuters were identified in the company's last major survey on the trend two years ago" – apparently downplaying the 1996 number.
FIND/SVP	1997	July 21, 1997 press release on etrg.findsvp.com/prls/pr97/telecomm.html, accessed 7/21/97; Gordon (1997); Gordon (1998)	Screening question: "Do you work at home during normal business hours one or more days a month?" Miller states same definition used in past FIND/SVP surveys. In Gordon (1998), Miller indicates that applying 1998 definitions to 1997 would yield a total of 10.5M telecommuters (6.9M full-time employees, 3.6M contract workers) rather than the 11.1M published number.
Cyber Dialogue	1998	Oct. 28, 1998 news release on www.cyberdialogue.com/news/releases/1998/10-28-sb-telecommuting.html, accessed July 19, 2001; Gordon (1998)	Exact definition of telecommuting used: "working at home for an outside employer during normal business hours a minimum of one day/month or more".
Cyber Dialogue	2000	Pratt (2002)	Cites Miller (unpublished).
Telework America	1999	Pratt (1999) (survey conducted by Joanne Pratt in association with Thomas Miller), and personal communication with first author, 8/16/2002	Pratt (1999): "In this study, teleworkers, also called telecommuters, are defined overall as employees or independent contractors who work at least one day per month at home during normal business hours." Personal communication: Includes multiple job holders.

Notes for Table 1 (continued)

Data Source	Year	Information Sources	Notes
	2000	www.telecommute.org/twa2000/research_results_summary.shtml, accessed 12/8/2000 (survey conducted by Jack Nilles)	Number calculated from reported total of 16.5M "regularly employed teleworkers" x 0.93 (reported proportion who are home-based or home- and center-based) x [0.54 (reported proportion who are employees) + 0.13 (reported proportion who are contract workers)]. Source comments that the 2000 TWA survey differs from the 1999 one in focusing only on "regularly employed" teleworkers, whereas the 1999 study included "occasionally employed" people. However, it goes on to say that "if the growth rate found in the year 2000 study were applicable to the total number of teleworkers found in the 1999 study, that would imply a total of 23.6 million teleworkers nationwide." A later document posted to the ITAC web site ("Telecommuting (or Telework): Alive and Well or Fading Away?", www.telecommute.org/aboutitac/alive.sthm, accessed 8/20/2001) refers to the 23.6M figure, without reference to 16.5M. A cynical view of this information suggests that the sponsors initially wanted to apply a more rigorous (and therefore presumably considered more appropriate) definition in the 2000 study, but then did not want to publicize a result that was lower than in the 1999 study. If true, this is a classic example of the results (as publicized) being influenced by external considerations.
	2001	www.telecommute.org/twa/twa2001/newsrelease.htm (survey conducted by D. Davis and K. Polonko of Old Dominion University); Pratt, personal communication to first author (3/8/2002). The full report on the 2001 survey costs $499; the information provided here is based on the freely-available sources noted	Reported total was 28.8M, which includes work done "on the road, in telework centers or in satellite offices." Table entry of 18.5M calculated from 28.8M x [0.217 (reported proportion working {only} from home) + 0.424 (reported proportion combining working at home with some other form of teleworking)]. However, since distinctions between forms of employment are not mentioned, the numbers probably include all teleworkers, not just salaried employees and contract workers. If salaried employees and contract workers comprised the same percentage of teleworkers in 2001 as they did in the 2000 TWA survey (67%), the relevant number of telecommuters in 2001 is 18.5 x 0.67 = 12.4 M. Pratt indicates that the 2001 number comparable to the 16.5M reported for 2000 is 15.8M. If 15.8M is deflated by the same factor of 0.62 used in the note above for the year 2000 (representing the proportion of the total who work from home and are salaried employees or contract workers), the result is 9.8M.

Table 2: Distribution of Days Worked at Home

Number (%) of workers working at home **Days/week worked at home ↓**	**SIPP (1997)**[1, 3] (worked only at home at least one day of a typical week in the previous month)			**American Housing Survey**[2, 3] (worked at home at least one day last week instead of traveling to work)			
	Mixed workers	*Home workers*	*Total*	*1995 (web)*	*1995 (Keil)*	*1997 (web and Keil)*	*1999 (web)*
1	1.725 (60)	0.511 (8)	2.236 (24.1)	2.152 (44.5)	1.234 (25.7)	1.465 (25.7)	1.469 (26.0)
2	0.604 (21)	0.192 (3)	0.795 (8.6)		1.042 (21.7)	0.988 (17.4)	1.014 (18.0)
3	0.201 (7)	0.319 (5)	0.521 (5.6)	0.854 (17.6)	0.586 (12.2)	0.647 (11.4)	0.652 (11.6)
4	0.115 (4)	0.192 (3)	0.307 (3.3)		0.322 (6.7)	0.304 (5.3)	0.283 (5.0)
5	0.201 (7)	3.576 (56)	3.777 (40.8)		0.763 (15.9)	1.508 (26.5)	1.408 (25.0)
6	0.0288 (1)	0.639 (10)	0.667 (7.2)	0.917 (19.0)	0.293 (6.1)	0.275 (4.8)	0.251 (4.5)
7	0 (0)	0.958 (15)	0.958 (10.3)		0.562 (11.7)	0.507 (8.9)	0.561 (9.9)
Not reported	–	–	–	0.916 (18.9)	–	–	–
Total population (millions)	2.875 (100)	6.385 (100)	9.260 (100)	4.839 (100.0)	4.8 (100.0)	5.694 (100.0)	5.639 (100.0)
Average days/week worked at home	1.8	4.9	3.9	–	3.3	3.4	3.4

[1] SIPP: Source is Kuenzi and Reschovsky (2001). "Home" workers are those who worked only at home, while "mixed" workers worked at least one full day at home in the preceding week, but also worked elsewhere. Numbers are calculated from the percentages given in Figure 1 of the source.

[2] AHS: Web source for 1995: www.census.gov/hhes/www.ahs.html, "National Data", "Publications", "1995 Supplement". Figure 2 of Keil (2000) displays a bar chart showing the distribution of days worked at home in 1995 and 1997. The 1995 Keil numbers and percentages in the table above are approximations obtained from visual inspection of Figure 2, based on the reported total of 4.8 million. He apparently redistributed most of the 18.9% of people in the "not reported" category of the web data into the 5, 6, and 7 days per week categories. The 1997 and 1999 distributions were obtained by queries of the respective data sets on the Census web site at ferret.bls.census.gov/cgi-bin/ferret, accessed 8/6/2002. The 1997 distribution obtained in this way matches the bar chart in Figure 2 of Keil.

[3] All columns include self-employed as well as salaried workers; see further discussion in the text.

NOTES

[1] http://www.apta.com/stats/safety/natsafe.htm, accessed September 19, 2002.

[2] http://www.bts.gov/publications/tsar/2000/chapter3/transportation_fatalities_a_modal_picture_table1.html, accessed September 23, 2002.

[3] http://www.apta.com/stats/modesumm/bussum.htm, accessed September 23, 2002.

[4] In fairness, in the same article (p. 38) Drucker commented that "Contrary to what futurists predicted 25 years ago, the trend is not toward individuals working in their homes." His focus was on the decentralization of office work from high-density downtown business districts. However, "sound bites" such as "commuting to office work is obsolete", coming from an acknowledged expert, lodge in the public consciousness and have often been cited in support of the telecommuting phenomenon.

[5] Conversely, once the "new trend" becomes commonplace, they are likely to overreport evidence of a backlash or retrenchment or yet a different trend, as indicated by several recent articles suggesting that telecommuting "isn't working" (Armour, 2001; Garber, 2001).

[6] Pratt (1997) discusses 19 large-sample surveys that measure home-based work in some form. In view of the context in which the present study was undertaken, we focused on surveys offering population-wide estimates (rather than focusing on a specific segment of the population), available for multiple years, with the ability to distinguish salaried telecommuters and contract workers from home-based businesses.

[7] www.sipp.census.gov/sipp/sippov98.htm, accessed February 17, 2002.

[8] As indicated in the notes to Table 1, this number may actually be 10.5 million in terms of consistency with 1998 definitions.

[9] The source cited cautions that the 1997 and 2001 numbers cannot be directly compared, due to differences in question wording.

[10] I.e., "every day they worked, they reported working at home" (Kuenzi and Reschovsky, 2001).

[11] There are a total of 5.036 M = 1.841 M (mixed) + 3.195 M (home) "non-self-employed" or salaried workers, according to Table 3 of Kuenzi and Reschovsky (2001). 1.8 (1.841/5.036) + 4.9 (3.195/5.036) = 3.8.