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The sustainability of telework: an ecological-footprinting approach

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This paper demonstrates the importance of a comprehensive framework to assess how telework affects sustainability. Sustainability-policy evaluation rarely considers substitution effects despite broad recognition that overall lifestyles must be analyzed to gauge how policy-induced behavioral changes translate into net environmental impact. Case-study data indicate that telework has far-reaching, complex, and varied effects on lifestyle practices, with potentially important environmental implications. Because adjustments occur across numerous consumption categories, the assessment of telework’s environmental dimensions must move beyond single-issue studies and single-dataset analysis. Ecological-footprint analysis, in combination with qualitative data, can suggest solutions to sustainability problems.

KEYWORDS: environmental impact sources, commuting, environmental policy, human-environment relationship, case studies

Introduction

Both national and international institutions have launched policies to reduce the environmental impacts of consumerism in affluent nations (see, e.g., Cohen et al. 2005; Martens & Spaargaren, 2005; Sanches, 2005). However, single-issue policies may well result in an array of adjustments that ultimately have unanticipated combined effects. For example, policies aimed at decreasing automobile commuting curtail harmful emissions, but if these savings are then spent on foreign travel or consumer goods, the net effects on the environment may be negligible or even perverse. Even with all the attention given to sustainability-assessment tools and policies, the consideration of substitution effects or demand-side issues is not yet fully developed.1 For sustainability science to move forward, progress must be made both in conducting more thoroughgoing studies and in exploring the complex pathways that give rise to particular outcomes. This article provides an exploratory, but comprehensive, methodology to evaluate the sustainability implications of telework. Following Castells (2000), we can view the trend toward telework as a manifestation of broader socioeconomic and technological changes related to workplace restructuring and advances in information technology. However, as illustrated here, many environmental effects of this transition emerge through a complex set of individual adjustments.

The article begins with a definition of telework and an overview of its diffusion as a workplace practice. It then reviews the literature relevant to the environmental implications of telework that has accumulated over the past decade or so. A framework for individual-level sustainability analysis is then developed employing the concept of ecological foot-printing. The article uses two Canadian case studies to explore pathways and to provisionally measure the environmental effects associated with telework. The discussion highlights the importance of considering numerous environmental consequences to capture the full array of substitution effects and to demonstrate the potential range of ramifying changes that depend on individual circumstances and preferences. We conclude by considering research-design issues and the challenges of including additional sustainability dimensions.

1 Skaburskis (2006) shows, for instance, that while New Urbanist forms of development are thought to help achieve sustainable urban forms, the demand-side issues have not been previously considered. He finds that those residing in a New Urbanist community near Toronto have typically moved from smaller dwellings, or were planning on increasing their housing expenditures in the future. The demand-side analysis used in this case study questions the sustainability of New Urbanism.

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The Telework Trend

Telework is an umbrella term for the use of “information and communications technology to perform work ‘at a distance,’’ and thus includes salary, contractual, and self-employed workers, as well as after-hours work activity by commuters (Mohkhtarian et al. 2004). Telecommuters, or paid employees who work from home instead of commuting daily, are a subset of teleworkers and are the focus of current attention. By considering only full-time telecommuters, we hope to make behavioral responses distinctly visible.

While adoption of telework was slow during the 1980s, the subsequent decade’s information revolution resulted in considerable growth in new work forms (Doherty et al. 2000; Bailey & Kurland, 2002; Robertson, 2005; CTA, 2006). Technological progress, coupled with growth in the service and knowledge-based economic sectors, is creating increasingly location-independent employment positions (Yen, 2000; Sohn et al. 2003). At the dawn of the millennium, upwards of three percent of the American and European workforces were telecommuting at least some days each week, although estimates vary widely due to definitional differences and challenges associated with documenting this dynamic, frequently informal, and usually part-time work arrangement (Mohkhtarian, 1991; Mohkhtarian et al. 2004). There is, though, large variation in diffusion rates across countries and regions, with higher overall adoption in the United States than in Europe (Mariani, 2000; Wedigier & Niebuhr, 2000; Mohkhtarian et al. 2005). Recent evidence, however, suggests that telework in the United States may now be growing more slowly than previously the case (Mohkhtarian et al. 2005). Nevertheless, it is evident that telework, while currently undertaken by only a small proportion of the workforce, has achieved a degree of acceptability and potential for further growth. Furthermore, studying telework can illuminate our understanding of important sustainability implications of broader changes in work arrangements.2

A Framework for Analysis

At present, our understanding of the environmental implications of telework is limited. Most research to date has focused on the implementation, adoption, and growth of telework programs (Bailey & Kurland, 2002; Kitou & Horvath, 2003). Moreover, studies of impacts have typically had a disciplinary, single-issue focus, with only a few more comprehensive reports (e.g., Hopkinson et al. 2002; Schallaböck & Uitzmann, 2003). While the dynamic and complex nature of telework cannot be easily resolved, a broader framework would likely provide a more complete assessment of its environmental implications.

Sustainable development provides one comprehensive framework for examining telework. First popularized in the early 1980s by the International Union for the Conservation of Nature, the sustainable-development concept involves improvement of the quality of social and economic processes while remaining within environmental carrying capacity (IUCN et al. 1980; see also Wackernagel & Rees, 1996; Chambers et al. 2000). Telework could potentially affect multiple aspects of sustainability. We focus here on the environmental aspects of sustainability, while recognizing that the adoption of telework is often motivated by the pursuit of either corporate cost savings or productivity increases (DuBrin, 1991; McCune, 1998; Doherty et al. 2000; Mariani, 2000; Verespej, 2001; Atkyns et al. 2002) or employee optimism that such practices can improve their quality of life (Mariani, 2000; Mirchandani, 2000; EURESCOM, 2001; BT, 2003; Shaw et al. 2003). At the same time, telework is frequently promoted on environmental grounds because of its potential to reduce automobile use (e.g., Atkyns et al. 2002; Harpaz, 2002). However, some authors question whether the net environmental effects of telework are positive (Heinonen & Lahti, 2002), as various rebound effects, such as increased non-work travel and/or higher home-energy consumption, may offset the benefits of less commuting (Schallaböck & Uitzmann, 2003; Kitou & Horvath, 2003).

The environmental consequences of telework on land-use patterns, consumption behavior, and waste generation have not to date been comprehensively accounted for and the processes that give rise to behavioral adjustments are not well understood. More fundamentally, there is no generally accepted method for assessing the overall environmental implications of lifestyle changes such as telework (Devuyst & Van Volsem, 2001). Since lifestyle alterations are rarely

2 While telework is often enabled by some form of technology, the use of this technology and the act of working from home are by no means exclusive to formal teleworkers. Societal sustainability implications of information technology may in fact be difficult to infer by focusing on such a narrow segment of the workforce. The professionalization of the workforce is perhaps more closely tied with technological change; and with the growth of knowledge-intensive industries work is carried away from the traditional workplace in many instances, even if one is not labelled as a formal home worker (e.g., BlackBerries, laptops, cell phones). Future study can broaden the definition of telework to include many types of “mobile” work. See Helling & Mohkhtarian (2001) and Haddon & Brynin (2005) for classifications of different types of telework depending on extent, employment arrangements, and use of technology.
linear, combinations of decisions that can cause unexpected and offsetting results are likely to occur. Without assessing the complete spectrum of environmental consequences, the net effects will remain uncertain.

One way to tackle the measurement challenge is to use ecological footprinting (EF). EF has been widely adopted in assessment because of its comprehensiveness and capacity to relate consumption to sustainability. Wackernagel & Rees (1996), the creators of EF, define it as an environmental accounting tool “that enables us to estimate the resource consumption and waste assimilation requirements of a defined human population or economy in terms of a corresponding productive land area.” Total equivalent land area available on the planet is used to measure carrying capacity. It is assumed that humanity’s total EF can only temporarily exceed aggregate productive capacity, as seems to be happening currently, before the system collapses (Chambers et al. 2000).

As outlined above, implicit in the commonly accepted definition of sustainability is some acceptance of the concept of carrying capacity, or need to live within certain biospheric limits (Holmberg et al. 1999). The EF is one of the few sustainability tools that allows inferences on whether a specific socioeconomic, political, or behavioral modification moves individuals or society closer to consuming only “their share” of the earth’s total resources.

The EF approach has been widely used to compare environmental impacts of specific activities and to measure relative progress toward sustainability for various countries and regions (Wackernagel et al. 2002; Jorgenson, 2003; Senbel et al. 2003). Much of the work on EF focuses on its methodological foundations at national and international scales, though critics of the technique such as van den Bergh & Verbruggen (1999) and van Kooten & Bulte (2000) largely focus on its utility as a policy tool at the national level. However, EF has also been applied at regional scales by authors such as Wackernagel (1998) and Barrett (2001) and is gaining ground in applications such as tourism (Gössling et al. 2002; Hunter, 2002) and product assessment (Chambers et al. 2000). While some analysts have developed individual and small-scale applications of EF (Simmons & Chambers, 1998; Roy & Caird, 2001; Wood & Lenzen, 2003; Holden, 2004), few studies have critically considered the EF’s utility for small-scale sustainability assessment (Wood, 2003; Moos et al. 2006).

Teilework’s Environmental Sustainability

While scholars have devoted considerable attention to the transport implications of home-based telework, the same cannot be said for other potential environmental impacts associated within this work practice. The following discussion summarizes our knowledge of the environmental implications of telework, organized around the impact categories typically used in EF analysis—transportation, residence, energy, goods, services, food, and waste.

From an environmental perspective, transportation is of paramount concern because available evidence, while still limited primarily to California-based studies of early adopters, suggests that “vehicle-miles traveled are substantially reduced for those who telecommute, on days that they telecommute, for as long as they telecommute” (Choo et al. 2005). Studies from other countries confirm that telework is associated with reductions in automobile use (Wood, 2003), and there is little evidence of new travel generation for the individual (i.e., increases in personal travel). However, it is still unclear to what extent household- or aggregate-level trips might be induced (Helling & Mokhtarian, 2001; Hopkinson et al. 2002; Choo et al. 2005) moreover, telework can contribute to residential relocation, as recent evidence suggests that individuals adapt their residential choice to the flexibility that telework provides (EURESCOM, 2001). Particular concern has emerged that teleworking households may move away from central areas (Helling & Mokhtarian, 2001; Audirac, 2003; Tayyaran et al. 2003; Lake, 2004) and thus contribute to the economic, social, and environmental problems created by sprawl and low density development patterns that are common in most North American cities (Wiewel et al. 1999; Duany et al. 2000; Burchell et al. 2002; Krieger, 2004). At present, however, the types of longitudinal data needed to address these issues are limited (Helling & Mokhtarian, 2001; Tayyaran et al. 2003), and thus one can only conclude that telework-induced travel changes appear environmentally positive, though modest (Choo et al. 2005; Andrey et al. 2005).

There are also indications that living space expands for home-based teleworkers (Yen, 2000). Larger homes increase the EF through the consumption of materials related to construction, renovations, and yard size, as well as associated changes in interior heating and cooling. However, if the growth in telework is driven, as Cornford and colleagues (1997) observe, by “push factors of corporate downsizing” and not voluntary adoption, relocation to larger dwellings may not be significant on a net basis.

Other potential environmental impact changes are associated with increased home-energy use,
work-related purchases, and changed eating habits or other non-work activities. Of these adjustments, only energy use has received serious consideration, and studies have documented increased home-energy demand—though the extent to which home-energy use is offset by decreased workplace-energy consumption has not been determined (Hopkinson et al. 2002; Kitou & Horvath, 2003). As for the work process, the main effects appear to be an increase in electronic equipment, paper, and furniture at the telework site. Again, employer reductions may offset some of these impacts. Net effects could still be greater, however, due to the intensified use of technology or more rapid obsolescence. Additionally, more time spent within the home may influence non-work activities, such as eating and recreation, but these issues have not received detailed empirical consideration.

Finally, it is generally assumed that telework increases wastes disposed of through domestic systems (Hopkinson et al. 2002). Some of this quantity is offset by reductions in the volume of waste produced at the workplace, while some may represent new waste related to duplication of equipment or records. However, virtually no empirical literature exists on this topic either.

In summary, with the exception of transportation and energy use, the range and extent—and even the overall direction—of change in the environmental impacts associated with telework remains unclear. The present study examines telework’s array of environmental impacts and provides some exploratory data on their extent. This approach differs from previous investigations in considering a broader array of environmental impacts of this novel work practice and also uses EF to relate these effects to the planet’s carrying capacity. We know of only one previous study that attempted to connect telework’s transportation-related impacts to planetary resource constraints (Wood, 2003). This analysis demonstrated that commuting reductions for a sample of British teleworkers decreased individuals’ EF by 0.14 hectares on average, or approximately two percent of the total footprint.

The Case Studies

The empirical evidence for this investigation comes from two Canadian small-sample employer-based case studies. Case 1 is a large private-sector financial firm and Case 2 is a large public-sector employer. The employers provided the sampling frames for the surveys and contact lists of workers with formal telework arrangements. All of the individuals on the two lists were invited to participate in the study via e-mail contact. The response rate was 24 out of 51 for Case 1, and 9 out of 40 for Case 2. Participants in both cases were employed in professional, managerial, or administrative jobs that required them to travel to client meetings in dispersed locations.

For Case 1, the participants had residential addresses that spanned the entire country. For some of these individuals, telework had recently introduced as a condition of employment; other study participants had initiated telework arrangements on their own. The group consisted of 21 women and 3 men ranging from approximately 30 to 60 years of age. Respondents’ household demographics varied widely, from single adults with or without dependent children to couples living with or without children. Household incomes varied from Can$30,000 to over Can$100,000, and highest education level ranged from high-school diplomas to university degrees.

Case 2 consisted of nine public-sector staff, all working in the same department, who resided mainly in the various metropolitan centers of Ontario. Telework was a condition of employment. The sample consisted of four women and five men, all in households with a partner; four respondents had dependent children. Participants ranged from 30 to over 60 years of age. Household incomes were from Can$40,000 to over Can$150,000, and all participants had at least one university degree (and four held one or more post-graduate degrees).

For Case 1, participants provided qualitative information through personal interviews on how telework had changed their respective housing situation and personal behavior. In Case 2, we used an exploratory survey to shed light on the utility of the EF in this type of application. Questions were administered in a computer-based questionnaire and trans-
lated into an EF score. Information was collected for both case studies in the seven EF categories—transportation, residence, energy, goods, services, food, and waste.

Both surveys were designed to provide before-and-after comparisons, based on participant recall. The before-and-after design is more appropriate than cross-sectional data for gaining insight into whether telework is the agent of change in altering individuals’ environmental impacts, particularly when working with small samples where it is difficult to statistically control other variables. However, as the closing section will discuss, other challenges related to comparisons over time became apparent. A second design issue relates to the use of the individual teleworker as the unit of analysis for this investigation. The associated insights thus do not account for any offsetting changes by other household members or by the respective employers. This matter is also considered further in the discussion.

Results

Analysis of the data from the two case studies indicates that telework altered behavioral patterns for all participants. In many instances, changes occurred in the same category and in the same direction, but individual circumstances translated into differences in the extent of change. Two main findings emerge. First, telework affected a range of factors that, in combination, make overall impacts highly variable and difficult to predict. Second, for any given impact there were myriad pathways of change.

Case 1: Pathways of Change

For transportation, findings from Case 1 are consistent with previous studies, in that commuting trips were reduced and other personal-travel modifications were relatively minor, although changes occurred in both directions and in various ways. Fourteen participants (from a sample of 24) eliminated their daily commute completely with only occasional trips (i.e., once a month) to the office. Most other participants reduced commuting by two to four days per week. Accordingly, a large majority of participants reported traveling less overall after adopting telework. In some instances, the net travel reduction was related to the lack of a commute. In the words of one respondent,

I would say I drive less...there would be less use of my car overall.

Some respondents indicated that home-based work allowed more efficient travel, with better planned and combined trips, since it was no longer necessary to “rush home” after work to cook supper, pick up children from daycare, or look after pets. However, in a few cases, participants did note that personal travel was either induced by telework or increased overall. One respondent commented,

[B]ecause I am in a home office, I need to get out, so on the weekends I [travel to see relatives by car].

Another participant noted that her travel modes had changed. In this instance, the respondent’s flexible schedule allowed her to walk her children to school, as opposed to driving them on the way to work.

With respect to residential changes, findings indicate that telework can affect housing decisions and investments. Eleven respondents stated that they made at least some modifications to their homes (e.g., renovate basement, complete additions) due to telework. There was also evidence that telework factored into decisions regarding multiple-home ownership, for example, with one respondent dwelling in the country and another closer to the corporate office for days requiring office-based activity. Telework was also associated with relocation into larger dwellings for two of the 24 participants:

In fact [telework] was part of the reason why we moved [to the suburbs]...into a bigger home where I could devote one of the bedrooms to an office.

I moved from an apartment into a townhouse [partly motivated by telework] where I could have a separate room for my office.

As for energy consumption, several Case 1 participants noted that, when the home office was located in a basement, space heaters were required in addition to raising the central-furnace thermostat. For two respondents, space-heating requirements rose

6 A spreadsheet developed by Wackernagel et al. (2003) was used to assess an individual teleworker’s EF. Average consumption data for each component is available to calculate the EF for an average person in the United States (9.7 hectares). For average Canadian consumption data, the consumption values were scaled down to make the overall EF reflect their reported Canadian average (8.8 hectares). This figure assumes that the difference between the United States and Canadian data originates solely with respect to consumption (not the supporting land-conversion values) and that for each component, consumption is proportionately less. The net effect of this assumption, however, should be minimal because the present undertaking is mainly concerned with changes in EF, not absolute value. In the EF, seven impact categories are considered: transportation, residence, energy, goods, services, food, and waste.
due to an increase in dwelling size, and in the households of three participants electricity consumption increased due to more frequent meal preparation within the home and use of electronic equipment. In fact, when asked generally about the comfort of their home offices or the drawbacks of telework, 11 of the 24 participants specifically noted an increase in electricity and space-heating use. The comments of one individual are instructive:

There is an increase in heating and electricity cost. When [I was not working from home] I kept the thermostat at about 17 [degrees Celsius], and now of course it has to be higher because I am home all day.

The interviews also revealed that telework increased goods consumption in certain instances (e.g., furniture, electronic equipment), but prompted a decrease in other areas (e.g., clothing). All of the respondents in this case study acquired an additional computer, fax, printer, scanner, and telephone—paid for by the employer. Fifteen teleworkers purchased additional furniture, ranging from a new chair to completely new office furnishings. One participant explained this upgrade in the following terms:

[Due to working from home] I got a filing cabinet, a desk that has a bookcase on top of it…I’ve got a chair, that is an ergonomic chair. And I’ve got a protector plastic mat on the floor.

At this point it remains unclear as to how many of these acquisitions were offset by a corresponding decrease in goods at the workplace. It is evident from our interviews that some compensation did occur. For example, one respondent reported that her customary work desk was simply sent home, and, in most cases, employees no longer retained a dedicated workspace at the central office. However, we also heard accounts of non-telework-related acquisitions. Eight participants purchased extra furniture and/or stereo systems, or redecorated their houses because they now spent more time at home. There was also indication from two respondents that working from home reduced the lifespan of their office equipment because of a need for more frequent updates to stay connected with the workplace. It was not, however, clear whether actual updates were more frequent than under prior circumstances or whether there was a perception of increased frequency due to having to make the purchases oneself. In addition to these direct effects on consumption, the new work practices also altered the acquisition of products not normally considered. For example, one respondent reported that

I used to have a closet full of clothes that I used to wear five days a week…but I really don’t need that much anymore [working from home].

Another noted,

I need more garbage bags, more light bulbs, more storage containers and a shredder working from home.

Participants also indicated an increased type and quantity of services consumed. All of the Case 1 participants reported installing an extra Internet and phone connection due to telework, and five indicated more frequent use of courier services to communicate with the central office. For example, a respondent observed specifically,

The courier comes almost every day [now that I work at home].

In terms of personal services, some Case 1 participants discussed how they were able to reduce their external laundry or dry-cleaning requirements. However, some also noticed an increase in their spending on hotels/motels when visiting the central office, because it was now further from their homes.

With respect to food, several participants discussed how telework had caused a shift to healthier diets (i.e., increase in vegetable consumption, decrease in meat consumption), which would logically decrease food-related environmental impacts. A reduction in expenditures on restaurant meals was also frequent. In fact, eight participants made specific comments about their changed eating habits. A representative observation was,

I cook more [working from home] than I used to [working from an office]…because I’m home right at 4:30 I make a real supper most nights, instead of picking up a cooked chicken at [the grocery store] on the way home or whatever…so I cook more.

Participants also generally indicated that working from home allowed them to reduce lunch expenditures. When asked how home-based work affected participants’ health, eight reported a positive change in their diet. For example:

I ate very healthy [working from home]…I would often eat carrots as my snack
food…that was huge… [for lunch] I had a poached egg or something like that rather than eating junk food at a restaurant or cafeteria.

Respondents attributed these dietary changes to a more flexible schedule and easier access to nutritious food. Only one participant noted a negative change in diet.

Finally, the interviews revealed that telework likely raised waste flows into the municipal system, primarily due to an increase in consumption. There were, though, indications of elevated recycling rates, as captured in the following comment:

You know when I am finished with my files I write on the back of them, it is my scrap paper, whereas [working from the corporate office] I felt obliged to throw all that stuff out.

**Case 2: The Magnitude of Change**

The second case study involved data gathering on consumption from a sample of public employees. In a self-administered survey, participants were asked to indicate the percentage change that occurred in their behavior in all EF categories since taking up telework and specify how much of this change could actually be attributed to telework as opposed to other lifestyle factors. These percentage changes were then combined with data on the average Canadian EF to estimate the change in EF due to telework. This approach assumes that these teleworkers, as a group, were average in their behavior before they began teleworking. Participants were also asked to comment on difficulties they encountered in answering the question.

The findings confirm that telework influences many aspects of participants’ lives and the extent of change for different impact categories is variable across study participants (Figure 1). Interestingly, for these respondents, all of the net effects were increases in the EF, indicating that telework’s sustainability effects are not guaranteed for every individual. Figure 1 illustrates the change in EF in each of the six impact categories for the nine respondents that comprised this case study. Each bar corresponds to a specific respondent, and the right-hand total indicates the net change in EF for each participant.

Increases in total individual EF ranged from approximately 0.3 hectares to over 1.1 hectares. For purposes of comparison, the current Canadian EF is 8.8 hectares, and approximately 1 hectare can be gained from an extra 10-hour trip by airplane each year. Hence, the change in EF due to telework makes a sizeable contribution to the total for some sample participants. In terms of the six consumption categories, food showed the least degree of change. Four participants reported no change, four others decreased slightly the food component of their EF due to adjustments in their meal preparation, and one noted the opposite trend.

The next four consumption categories—housing, transportation, goods, and services—all increased or remained unchanged for each of the nine participants. Housing contributed almost half of the total increase in EF for five participants and about 30% of the total increase for two participants. Two other respondents, however, evinced little change in their housing footprint. Transportation increased for most participants (despite the opposite trend reported in the literature), although these changes, as discussed in the next section, seem attributable to factors other than telework alone. Goods consumption increased for all participants, but ranged from less than 0.1 hectare to over 0.35 hectare. The extent of the change depends on whether participants attributed purchases of secondary-household items, in addition to office furniture, to telework. Increases in service consumption also varied by participant, from less than 0.1 hectare to less than 0.3 hectare. However, six of the nine participants increased the service component of their EF on the order of 0.1 hectare. These increases are mainly related to greater use of the Internet and courier services. One participant required regular hotel accommodation due to spatial separation of her home from the central office.

Finally, changes in EF in the waste category fluctuated widely among participants. One individual

7 On a hypothetical note, even if all nine participants had achieved reductions in the transport component of their overall EF that were similar in magnitude (0.14 hectares) to those in Woods’ (2003) study of British teleworkers, eight of the Canadians would still have experienced an increase in total EF.
attributed almost half of the increase in total EF to waste, while another respondent saw a change similar in magnitude, but opposite in direction. Two other individuals saw more modest decreases, and five increased the waste component of their EF by approximately 0.1 hectare. The difference in direction depends on whether participants felt that working at home allowed for more re-use of materials and more stringent recycling systems. Increases in waste are related to the duplication of equipment and the transfer of documents between home and central offices.

Results in the Context of the Literature

Table 1 summarizes the direction of change for each impact category, as generally reported in the extant literature and the two Canadian case studies described here. Apart from transportation data, the direction of change is consistent across the three information sources. The food component of the EF decreases, but residence, energy, goods, services, and waste increase. Work-related transportation impacts for the Case 2 participants were found to increase due to job-responsibility changes over time. In fact, the three participants who reported less work travel were the only ones who held the same job, or jobs with similar travel requirements, in the before-and-after periods. Six other individuals moved on to other positions. At a societal level, the opportunities afforded by telework resulted in an enlarged transportation footprint. Nevertheless, the before-and-after comparison at the individual level does not allow for a firm determination of telework-induced transport changes per se, because changes in jobs confound these adjustments.

| CATEGORY       | LITERATURE | CASE 1 | CASE 2 |
|----------------|------------|--------|--------|
| Food           | N/A        | ↓      | ↓      |
| Residence      | ↑          | ↑      | ↑      |
| Energy         | ↑          | ↑      | ↑      |
| Transportation | ↓          | ↓      | ↑      |
| Goods          | ↑          | ↑      | ↑      |
| Services       | N/A        | ↑      | ↑      |
| Waste          | ↑          | ↑      | ↑      |
| Total          | ↑ or ↓     | N/A    | ↑      |

*See text for explanation

Both case studies, however, provide a basis for considering various theories of environmental behavior, particularly the importance of barriers to change (McKenzie-Mohr, 2000; Kennedy et al. 2001). In many instances, telework removed a barrier to a preferred and more sustainable lifestyle change. For example, the replacement of a rigid work schedule with a flexible means of managing work allowed participants time for exercise, healthier eating, and improved housework and childcare management (see also Shaw et al. 2003). Similarly, the elimination of commuting time created opportunities for respondents to plan travel more efficiently. In other instances, however, telework introduced new motivations for environmentally harmful behaviors that were not curbed by structural barriers. For example, the social isolation caused by telework appears to motivate increased personal travel, and the need to spend more time at home spurs the purchase of new home-entertainment systems. In summary, the study of barriers alone cannot completely illuminate the various lifestyle changes that accompany the adoption of telework, and data limitations prohibit firm conclusions with respect to behavioral change. Nevertheless, this topic warrants further investigation as a way of facilitating change toward sustainability.

Research Design and Sustainability Assessment

The current study also provides a basis for commenting on research-design issues more broadly related to sustainability assessment. The identification and measurement of change is generally based on before-and-after comparisons, especially when the sample size is modest. However, participants in both case studies had difficulties with recall and were not always able to separate telework impacts from other lifestyle changes. In other before-and-after comparisons, workers have been observed in their office settings and then again after telework was introduced (see, e.g., Statistics Canada, 1995). However, this methodology requires advance appraisal of organizational decisions and cannot avoid the problem of “honeymoon” effects unless the study has a long duration. An alternative approach is to use a with-without design in which data on office workers and teleworkers are compared after controlling for external variables. However, large public data-sets do not yet provide sufficiently detailed information. In sampling teleworkers, it is difficult to generate large respondent pools because telework is often informal and institutions are typically reluctant to allow researchers to interview employees on organizational policies (McCloskey & Igbaria, 1998; Bailey & Kurland, 2002). Therefore, before-and-after comparisons can provide a reasonable indication of telework as an agent of change, but some impact categories must be interpreted with more caution than others.

In terms of the EF, the collection of self-reported data has limitations. Case 2 participants, for instance, were asked directly about consumption patterns. The main problem here is that participants generally lack sufficient knowledge to provide accurate consumption data in the form required for EF calculations.
(e.g., weight of furniture owned). Respondents were therefore asked to place themselves within a category of percent change. Nevertheless, the accuracy of the data was constrained because some participants did not track certain changes. Thus, the reliability of self-report data as a measure of environmental impacts has not been addressed in previous EF studies, a potentially important issue regarding individual behavioral change (Hamilton, 1985; Newell et al. 1999; Yu et al. 2000; Parslow et al. 2003; Tucker, 2003).

Another matter that warrants comment is the use of the individual as the unit of analysis. In transportation-related studies of telework, it is widely recognized that other household members are crucial to gaining a complete picture of telework-induced travel changes (Helling & Mokhtarian, 2001; Andrey et al. 2005). There is also growing appreciation that travel effects are even possible at the societal level, such as induced or latent travel demand when congestion is indeed reduced. For other impact categories, such as goods and services, the actions of employers, rather than other household members, are fundamental to understanding the extent and nature of overall change. In the current study, these matters could not be addressed completely because our focus was on the individual teleworking employee. For example, it is known that the organization employing Case 1 participants did eliminate some office space previously dedicated to the affected work groups, while the Case 2 employer fully duplicated office space. However, without additional data we cannot ascertain the net effect of these different institutional decisions. Efforts to gain insight into firm decisions may be difficult and costly. Nonetheless, including other household members in transportation research is common and past EF studies have already incorporated research designs that measure consumption at the household or organizational level (Roy & Caird, 2001; Wackernagel et al. 2003; Wood, 2003; Andrey et al. 2005). The light that integrated assessments of telework can shed on behavioral processes and the environmental impacts of changing work arrangements can aid efforts to secure funding for comprehensive studies.

Furthermore, the EF does not require an understanding about causal relationships between various influences on individual behavior. While this simplifies analysis and ensures all impacts are considered even if causal relationships are not understood (obviously, often the case in individual behavioral change), it also renders the tool less useful as the basis for planning and policymaking. For instance, an EF provides no details on the number and type of automobile trips and the motivations that caused them, yet planners and policymakers require this information for transportation management. Despite this drawback, the EF creates a common denominator that allows for the comparative analysis of various opposing impacts. Moreover, other environmental indicators often require analysts to subjectively weight relative impacts.

The Three Dimensions of Sustainability

Although this paper only considers environmental sustainability, it is important that the three dimensions of sustainability—environmental, social and economic—be addressed so that a comprehensive understanding of telework can facilitate appropriate policies and practices. This is easier said than done. While a range of qualitative sustainability-assessment tools is available to capture all three dimensions, it is usually necessary to make value judgments by assigning weights. While these tools may work at larger scales, where sustainability assessment includes broad community participation, they are unable to provide a consistent multi-scaler basis for sustainability analysis and hence would not work well at the individual level. A multi-tool research design, using a combination of interviews and surveys, in conjunction with spending and travel diaries, would be required to gain sufficient insight into all dimensions of sustainability. The environmental data for the Case 1 participants discussed above are complemented with rich and varied data on the social implications of telework, as reported in Shaw et al. (2003) and Johnson et al. (2007). However, the study’s intensive nature resulted in a modest sample size which necessarily limits the generalizability of the results. Also, several steps were integral to getting support from prospective participants: contact through their employer with a promise of absolute confidentiality for individual responses; (but that mutual concerns and best practices would be shared with corporate management); contact by the principal researcher; and payment of an honorarium for each of the study components. Even so, the sample size under such circumstances is likely to be modest and the costs of conducting a true before-and-after study on a statistically representative sample are large. These dilemmas make it difficult to adequately address the trade-offs among the three dimensions of sustainability.

Therefore, rather than weighing environmental versus social or economic gains/losses, innovative research may suggest sustainability solutions to try to ensure benefits within each of the three dimensions and to optimize particular salient benefits. Because of recognition that telework benefits are not automatic, a European Union project, for example, has begun to advise employers and employees on designing telework programs to ensure overall social gains (Hopkinson et al. 2002). Heinonen & Lahti (2002) also
speculate that telework may have detrimental effects and thus recommend the concept of “eco-managed” teleworkers, where employers and employees agree on best-practice patterns of telework and mobility. Preferred actions include eliminating or sharing workplace office space, avoiding duplicating equipment and corporate reports, moving existing office furniture into home offices, and discussing travel behavior with teleworkers. Laura Johnson (1999, 2003) has illustrated how satellite offices—commonly referred to as telework offices or telecenters—could reduce fears of social isolation commonly associated with home-based telework. Perhaps all that can be done in practice is to highlight a comprehensive range of social, economic, and environmental impacts that can arise from telework so that planners, policymakers, employers, and employees can make informed choices (e.g., Hopkinson et al. 2002).

Conclusion

The interview and questionnaire data assembled for the current study indicate that, beyond creating far-reaching changes in participants’ lives, telework has potentially important environmental impacts. Of particular interest is that the range and pathways of change varied markedly across individuals—even among respondents at similar life stages with similar jobs—and this lack of congruity highlights the complex nature of the behavioral responses associated with telework. Because changes occurred in various categories, assessment of telework’s environmental implications must move beyond single-issue studies. For example, the assumed benefits of telework for society at large must be carefully examined to avoid promoting telework’s ostensible tendency to reduce air pollution only to find that other harmful effects offset these gains. We have provided here an exploratory investigation that we hope will be the start of a long succession of studies on the sustainability implications of telework.

While researchers must be aware of data limitations, the EF framework works well in this context because it considers a broader array of environmental consequences in relation to carrying capacity. The EF has been applauded for being an easy-to-use sustainability-assessment tool. However, at this point it is still unclear whether it can illuminate our understanding of sustainability solutions. The qualitative information provided by the first case study tells us how to enhance the sustainability of policy-induced socioeconomic changes. The EF, however, can inform us how far from sustainability we actually are—an important initial step in trying to find effective solutions. Qualitative information on pathways of change therefore seems to complement quantitative estimates of environmental consequences. Indeed, we would argue that this type of comprehensive thinking should guide assessments of behavioral responses and socioeconomic changes in the sustainability context in general.

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