TRANSPORT RESEARCH LABORATORY

Monitoring and evaluation of a teleworking trial in Hampshire

Prepared for Hampshire County Council

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(Southampton University) and University of Portsmouth

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Executive Summary

This report describes the evaluation of a trial of teleworking among a group of employees in Hampshire. Teleworking enables employees to work from home or at offices closer to home on a full or part-time basis by using telecommunications equipment. The trial was implemented and evaluated as part of the ENTRANCE project.

ENTRANCE demonstrates ways of improving travel and transport in European cities, leading to energy savings, lower emission levels and a better quality of life. The schemes involve public transport improvements, to encourage the use of this mode of travel in preference to private vehicles, but also involve promoting alternative patterns of travel (through teleworking and cycling), and techniques for managing traffic congestion.

The ENTRANCE project is funded partly by the European Commission's Directorate-General for Energy and partly by the cities and other partners involved. The project was launched in February 1994 and is led by nine cities in eight member states. The evaluation in Hampshire was carried out by TRL, the University of Southampton and the University of Portsmouth, for Hampshire County Council.

In Hampshire the aim of the study is to raise awareness of energy and environmental issues by demonstrating various applications in and around Southampton and Portsmouth. The evaluation aims to assess the energy consumption benefits and the associated environmental benefits due to individual schemes, and to determine the impacts of the applications in behavioural and economic terms.

This report describes the evaluation of the teleworking application. The aim of the trial was to demonstrate energy savings and environmental benefits by enabling a number of employees to telework away from their usual office locations on a full or part-time basis.

In the trial, four organisations formally introduced teleworking into their working practice for selected employees. In all cases, the teleworkers worked at home for part of their working week, using telephones to communicate with the office. Some used additional means of communication and most used computers.

The travel behaviour, working practices, opinions and aspirations of the 24 new teleworkers were monitored before and after teleworking commenced. A parallel (or 'retrospective') study addressed similar issues for a sample of 19 established teleworkers who had been teleworking for part of their working week for between two and four years.

The results of the trial reflect the behaviour and opinions of a small sample of individuals who might be classed as atypical of the population at large, with above average incomes, distances travelled to work and levels of household car ownership. Nevertheless, it could be argued that these are representative of teleworkers, particularly those who have adopted this working practice at a relatively early stage in the development of teleworking.

A potentially significant longer term impact of teleworking is that it enables people to move home or job; this provided additional benefits to teleworkers, but results in longer commuting distances (and additional travel costs) on the days when commuting journeys are made. Two of the established teleworkers in the study had already moved to live in a more desirable location further from the office.

In accordance with other studies, part-time home working appears set to be the main form of teleworking, with individuals spending one or two days per week working at home. The extent of travel impacts at an aggregate level was limited accordingly. The average frequency of teleworking was 1.2 days per week. There was some evidence that this may increase as teleworking becomes established, as the more established group teleworked for 1.7 days per week on average, with a higher rate among those who had teleworked for four years.

The survey results revealed salient observations concerning the uptake of teleworking and its consequences in terms of energy, environmental, economic and behavioural impacts. All but one of the teleworkers in the trial wished to continue teleworking. This encouraging result emerged following first-hand experience of teleworking and in many cases a change in attitude. All the teleworkers were naturally seeking personal benefits from teleworking, and the proportion who saw no disbenefits to themselves doubled to 30% once they had experienced teleworking. In practice many of their expectations were exceeded, and many of the anticipated difficulties and problems did not arise, although some expectations were not met. The main benefits to employees were associated with flexibility (in work and home life), uninterrupted working time and those related to the journey to and from work. For employers, the benefits outweighed the disbenefits, with the main difficulty being concerned with managing from a distance.

Although most teleworking days were full days, many teleworkers teleworked part-days to accommodate business commitments on some occasions, so they still made a commute journey, though not necessarily during the peak period. Non-commute travel did not increase as a result of teleworking. High car ownership per licensed driver in each teleworking household meant that the teleworker's travel-to-work vehicle was not generally used for other purposes on teleworking days.

Teleworking resulted in a substantial reduction in weekly mileage and number of journeys, although the teleworkers had above average commute distances. The number of cold starts made by teleworkers' vehicles was reduced on teleworking days. This in turn led to a reduction in overall vehicle emissions and travel-related energy consumption of about 45 per cent on teleworking days compared with normal working days. With the average frequency of teleworking occurring in the trial, savings of fuel and pollutant emissions were estimated to be around 11 to 21 per cent in an average working week. Thus the objectives of the application were achieved.

The trial took place during the spring, summer and early autumn. Domestic energy consumption, notably heating, was not therefore high and little impact was observed as a

consequence of teleworking. Estimates from the teleworkers suggest that domestic energy consumption would increase in winter months but would only marginally offset reductions in travel-based energy consumption.

Direct financial benefit to teleworkers was not a prime motivation to telework. However, indirect economic benefits were apparent for employers. Productivity increases and improved staff morale were widely cited as benefits for the teleworker, and therefore in turn the employer.

The economic evaluation was based on savings arising from the changes in travel behaviour, set against costs of buying and maintaining equipment provided by employers. Savings in distance travelled by car amounted to around 3,000 miles per year for the trial teleworkers and 4,000 miles per year for the established teleworkers. Annual time savings averaged 68 hours and 94 hours respectively. The average cost of equipment purchased by employers was around £1,700 per teleworker.

The economic evaluation showed that on the basis of the assumptions used, and at the frequency of teleworking during the trial, the costs of additional equipment and maintenance would be outweighed by the value of the benefits in fuel, vehicle operating costs and travel time over a five year period. For the established teleworkers, where teleworking was rather more frequent, these costs would be outweighed by the benefits over a three year period.

1 Evaluation plan

This section outlines the evaluation plan that was set out at the beginning of the project. Certain changes of emphasis and content of this plan took place during the study. However, this section sets a platform from which to report in more detail on the activity and evaluation that actually took place.

1.1 Description of the application

Teleworking involves employees using telecommunications equipment to work from home or at offices closer to home for part of their working week. The Teleworking Application involves a trial with selected individuals from a number of organisations working from home rather than in the office. It was anticipated that teleworkers would spend some time in their offices and some working from home. The evaluation was based on monitoring patterns of activity to identify changes in behaviour, energy use and emissions.

The objective of the trial was to demonstrate the overall energy savings made by allowing employees to telework all or part of the time.

Although teleworking as a working practice has been technically feasible for a number of years, the proportion of the workforce who have become teleworkers, even on a part-time basis, appears to have remained small.

The trial involved individuals from four organisations taking part in a 'before and after' study. In addition, the study included a survey of established teleworkers who had been teleworking for at least a year for part (but not all) of their working week.

1.2 Expected impacts

Working from home was expected to change the travel patterns of the teleworker. It was also anticipated that travel patterns of other members of the household might also change as a result of the availability of the teleworker's car during the working day. The reduction in energy use and emissions therefore needed to be balanced with any increased use of the vehicle. Changes in travel patterns were also expected to lead to savings in vehicle maintenance and running costs.

For the employer there was expected to be an additional cost of providing equipment, but this could potentially have been offset by increased productivity and reduced energy use in the work place (heating, lighting, etc.).

1.3 Indicators to be measured

The following indicators were required for the evaluation:

- travel patterns (journey length, frequency and purpose) for teleworkers and their households;
- energy consumption and energy efficiency, both in the home and at work;
- pollutant emissions for the teleworkers' vehicles;
- teleworkers' attitudes, including motivation, productivity and efficiency;
- employers' attitudes to teleworkers and productivity.

1.4 Measurement methods

Data collection for the evaluation was by questionnaire survey, both face-to face and self completion, and self completion of a travel diary. These surveys were carried out before and during the teleworking trial. During the 'before' period participants were asked to complete a daily travel diary over a four week period. They also completed a questionnaire exploring attitudes to and motivation for participation in the trial, and the extent to which they already worked at home. During the trial similar surveys were executed to determine amount of time worked at home, motivation and attitudes. It was also planned to make estimates of additional heating costs and phone bills. Surveys of employers were carried out to assess the effectiveness of teleworkers compared to people with a traditional work place.

An additional survey was carried out among employees who had been teleworking for part of the working week for at least a year. This used questions which were compatible with those in the questionnaire survey of the trial participants. The survey provided information on how teleworkers' habits developed in the longer term and an indication of whether the patterns developed during the trial were likely to be sustained in the future.

1.5 Analysis

1.5.1 Energy

The change in mileage for the teleworkers' vehicle was used to estimate savings in fuel consumption and maintenance costs. This was expected to be balanced with the likely increased use of energy within the home.

1.5.2 Environment

The effect of teleworking on emissions was calculated from an analysis of the journey and vehicle logs, making use of appropriate emission factors (see Section 4.1).

1.5.3 Economic

The costs and benefits arising were expected to be shared by the employer and the employee. The cost of equipment and overhead costs (phone bills, additional heating and lighting at home) were expected to be balanced against savings in travel costs for participants. It was not possible in this limited trial to assess savings in accommodation costs for employers. It was expected that an assessment of increased efficiency would be made if employers were able to do so.

Where employers offered a subsidy to teleworkers this was included in the cost/benefit balance.

The time saved by the teleworker in not travelling to the employer's premises was valued and included in the analysis.

1.5.4 Behaviour

Attitudes and advantages and disadvantages as perceived by the teleworkers were determined, particularly with regard to their own productivity and efficiency. In addition employers' attitudes to teleworking were sought. Travel behaviour, both of the teleworker and members of their household, was analysed.

2 'Before' survey

2.1 Introduction

Between 22 January and 14 June 1996, 24 individuals from four organisations joined the ENTRANCE teleworking trial. The trial consisted principally of two stages; namely a 'before' stage and an 'after' stage. The 'before' stage comprised a period of approximately one month, during which information was collected on an individual's behaviour in the absence of the option to telework. The 'after' stage then comprised a period of around six months, when similar information was collected where the option to telework existed. The 'before' stage involved the following survey instruments:

- a self-completion questionnaire;
- a face-to-face questionnaire interview;
- a self-completed record of daily travel.

The four organisations involved in the trial were: the Automobile Association (AA), the British Broadcasting Corporation (BBC), Gifford & Partners consulting engineers (G&P), and Hampshire County Council (HCC). The BBC had the most teleworkers in the trial (eight), followed by Gifford and Partners with seven, the AA with six, and Hampshire CC with three, each from different departments.

The questionnaire was used to collect factual information about the individual. The interview was intended to obtain information concerning the motivations, aspirations and opinions of each participant in addition to behavioural information. The record of daily travel consisted of a travel diary, to record details of each journey made by the individual, and a vehicle log that recorded details of each journey made using the individual's normal 'travel-to-work' vehicle. A minimum period of four weeks (including weekends) of daily travel information was collected for each individual.

This section summarises the information from the 'before' survey.

2.2 Self-completion Questionnaire

2.2.1 Introduction

During the first week of the 'before' survey participants were asked to complete a mail-back questionnaire. It comprised six sections asking for basic details concerning their home, their travel patterns and their vehicle use. The aim was to seek factual information to identify the underlying patterns within the sample as a whole and to outline some of the characteristics of participants in each organisation.

2.2.2 Results

2.2.2.1 Domestic information

Participants were asked to provide some information about their domestic circumstances, including how long they had lived there, and how many people there were in the household. The results are given in Table 1.

The distribution of household types (Table 2) shows that there were two adults living in most of the households, of whom two-thirds had children. Adults were defined as being aged 18 or over.

Table 1 Domestic information

Question	*Mean*	*Standard deviation*	*Range*
How long have you lived at your present address?	6 years 4 months	5 years 4 months	10 months to 20 years
How many people live at this address?	3 people	0.95	1 to 4

Table 2 Distribution of household types

Number of adults	*Number of households and number of children*
1 adult	1 with no children
2 adults	8 with no children 4 with one child 7 with two children
3 adults	2 with no children
4 adults	2 with no children

2.2.2.2 Vehicles

A total of sixteen households had two cars, six had one car, and two had three cars.

Availability of a car has a direct impact on energy use, and this was expected to vary according to the number of people holding a driving licence. In this study two people on average in each household held a driving licence (with a range between 1 and 4). In only three households was there an adult without a driving licence. The average number of drivers per car in each household was 1.25, with a standard deviation of 0.58 and a range from 0.5 to 3.0.

2.2.2.3 Current travel arrangements

Table 3 summarises information on travel arrangements at the time of the 'before' survey. Only one of the participants travelled to work by train, all the rest travelled by car. (The 20:30 departure time in Table 3 considerably distorts the mean, the next latest departure time is 10:00.) The mean time taken to travel to work in Great Britain in 1995 was 24 minutes (Department of Transport, 1996). Eleven people used more than one route for their regular journey-to-work. Only one person experienced any difficulty with parking at work in the morning.

2.2.2.4 Home details

Most participants (16) lived in a detached house, with four living in a semi-detached, three in a terraced house, and one in a flat. The median number of rooms was 6, with a range between 4 and 9.

Heating was fuelled by gas in 20 of the homes, by oil in two, coal at one and by electric storage heater at one. As mentioned earlier, 13 participants regularly worked at home, of whom 10 had a specific place to work; however none of these were usually heated during the day. For the three who did not have a specific place to work only one had heating. Although 11 did not regularly work at home, 4 of them had a specific place (1 heated, 3 not); while 7 do not (3 heated, 4 not). The way in which these houses were heated, with few

Table 3 Travel arrangements

Question	*Mean*	*Standard deviation*	*Median*	*Range*
How far is it to work?	23.4 miles	21.5	21.5 miles	5 to 75 miles
Time of departure to work:	08:13	-	07:56	06:15 to 20:30
How long does it take to get to work?	35 mins	-	38 mins	10 to 75 mins

being heated during the day, is likely to have an impact on the economics of teleworking when working-at-home is undertaken, particularly in the winter months.

2.2.2.5 Working patterns

Participants were asked questions aimed at identifying the way in which they worked and how they interacted with other people. The median number of telephone calls received in the course of a day's business was 16-20. Table 4 shows that most people had a high degree of face-to-face contact (13 described it as 'a lot').

Table 4 Level of face-to-face contact at work

Level of contact	*Number of participants*
A little	0
Some	1
Medium amount	6
Quite a lot	4
A lot	13

2.2.2.6 Salary and position

Participants were asked for some information about their salary and position in the organisation to enable a profile to be drawn of the teleworking participants and the results are shown in Table 5 and Table 6. Half of them were middle managers, and most of the rest had some managerial or supervisory responsibility. Salaries were above the national average of £18,300, and half were over £30,000 per annum. Only three participants had elements of performance-related pay in their salary.

Table 5 Position in the organisation

Position	*Number of participants*
Senior management	5
Middle management	12
Supervisor / junior management	3
Other	4

Table 6 Gross annual salary

Salary	*Number of participants*
up to £20,000	3
£20,000 to £25,000	4
£25,000 to £30,000	3
£30,000 to £35,000	7
£35,000 to £40,000	3
£40,000 to £45,000	2
£45,000 +	1

2.2.2.7 Company cars

Each organisation had a different approach to the provision of company cars for its staff. This was considered a potentially important element in assessing the impact of teleworking.

AA	all had company cars;
BBC	varied according to the requirement of the job rather than seniority;
G&P	only the senior manager had a company car;
HCC	none.

Distances travelled to work were shorter for Hampshire County Council staff than for those working in other organisations, as Table 7 shows.

Table 7 Distance to work

	Distance to work (miles)		
	Mean	*Median*	*Standard deviation*
AA	29.5	28.5	2.9
BBC	26.3	21.5	21.6
G&P	32.1	19.0	34.5
HCC	14.0	16.0	8.2

The mean estimated arrival time at work for each organisation was later at the BBC than at the others:

AA	08:20
BBC	09:30 (excluding one extreme value, otherwise 10.05)
G&P	08:10
HCC	08:05

2.2.3 Summary

The information provided by the participants shows a variety of domestic circumstances. Household composition varied from one adult living alone, to two households containing four adults. Eleven households included children under the age of 18.

All households had a car, and 18 of the 24 households had more than one car. Most adults in the households had ready access to a vehicle, with the mean number of drivers per car owned being 1.25.

The mean distance driven to work by trial participants was 20.9 miles. Only one of the trial participants travelled to work by train. By including this journey the mean distance travelled was 23.4 miles. The journey to work by all participants was on average 35 minutes.

Half of the participant sample regularly worked at home. Ten of these had a specific place of work within the home,

but none of these areas were normally heated during the day. The most common fuel for domestic heating was gas, for twenty of the participants.

The median pay band of the participants was £30,000 to £35,000, and most described their position in the organisation as 'management'. Most participants claimed to receive between 16 and 20 telephone calls a day, and also to enjoy a high degree of face-to-face contact in their work.

2.3 Face-to-face interview

2.3.1 Introduction

The questionnaire was completed by the interviewer and was largely based on pairs of questions, the first of which demanded a specific response and a second an explanation of that response.

2.3.2 Results

2.3.2.1 Working practices

Two-thirds of participants had considered working at home before 'very seriously' or 'quite seriously', which might suggest a willingness of employees generally to telework if presented with the opportunity. Those who had considered working at home before at least 'quite seriously' tended to be in higher management positions. This may imply that as the level of management increases, the demand for effective time management increases, and teleworking can play a part in this.

Over 60 per cent of participants had spent more than a week working at home during the past year; 62 per cent of participants also worked during all or part of the weekend at least once or twice a month. However, only 29 per cent of individual participants were in both of these categories.

For the majority of individuals (87 per cent), any weekend work currently performed was not a substitute for weekday work. Over three-quarters (79 per cent) of participants did not intend to work more at weekends once they began teleworking. Nearly a third (29 per cent) stated a clear objective to keep weekends 'work-free' and/or available for family activities. Some participants indicated an intention to be more productive during the week by teleworking, thereby reducing the need to work at weekends. Others considered that weekend work would not increase because teleworking represented a relocation of work in space and not time. Figure 1 and Figure 2 indicate the attitudes to home and weekend working before the teleworking trial commenced.

The implication of these results is that people expected to use teleworking to introduce some additional flexibility into the working week. Some expected to work more often at weekends, in some cases instead of time spent working in the week. Some participants indicated a desire for their employer to respect the total number of hours worked.

2.3.2.2 Attitudes to teleworking before the trial

Just over half (58 per cent) of participants anticipated teleworking part days (at least sometimes). In particular seven of the eight BBC participants were of this opinion.

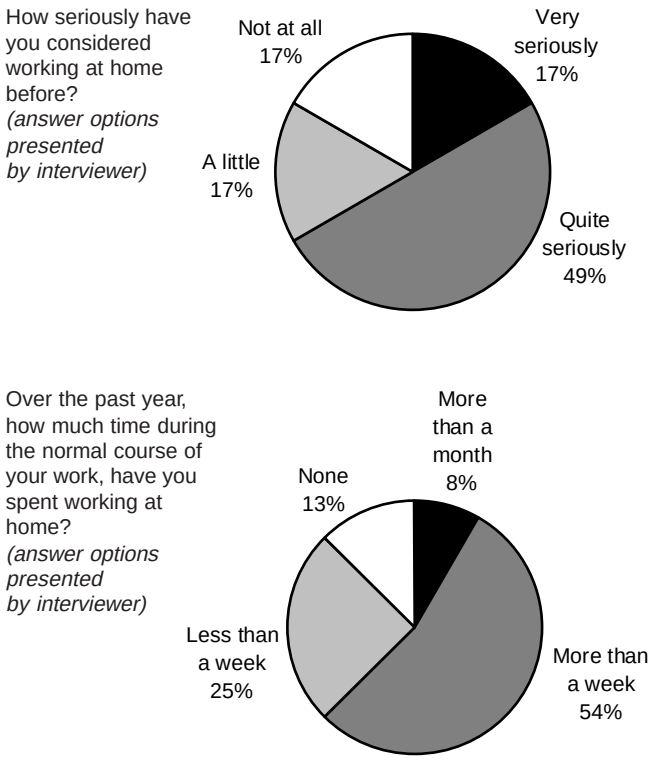


Figure 1 Frequency of working at home before the teleworking trial

Reasons included the need to attend meetings and the option of working at the office during the day and teleworking in the evening. The main reason against teleworking part days was that the commute journey would still take place.

Over half the participants (54 per cent) felt they would use the time travelling to or from work to adjust to the work or home environment. Nearly three-quarters (71 per cent) of participants expected to use at least some of the time formerly used in the commute to do some work. This concurs with earlier comments concerning the intention to use teleworking to achieve more work during the week to keep the weekend free for personal and family time.

The majority of participants (75 per cent) believed they would retain a distinction between their work and home lives once teleworking. Over half (54 per cent) of participants indicated that someone would be at home when they were teleworking at least some of the time. Almost a third (31 per cent) of these indicated that they (their child/children) would demand their attention for some of the time.

A majority (62 per cent) of participants considered themselves most productive in the mornings; 60 per cent of this group consequently expected to use teleworking to allow them to start work earlier in the mornings (taking advantage of the time formerly used for the commute journey). Two fifths (42 per cent) of participants did not consider that their times of productivity would influence when they chose to telework.

Figure 3 indicates some of the attitudes to teleworking before the trial took place.

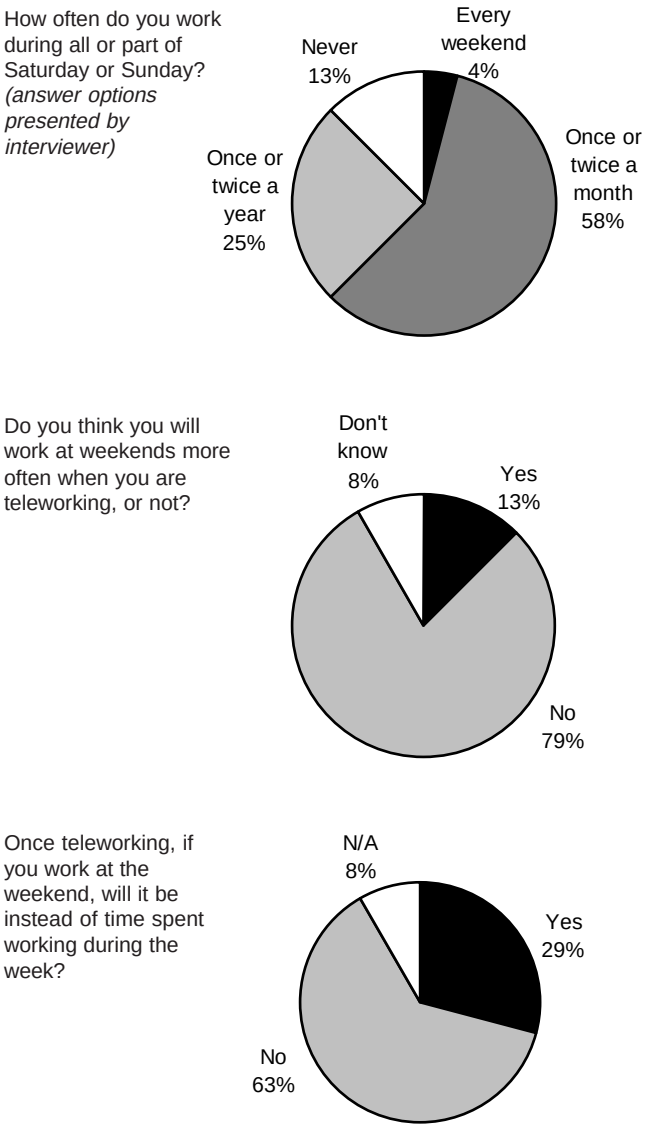


Figure 2 Attitudes to weekend working before the teleworking trial

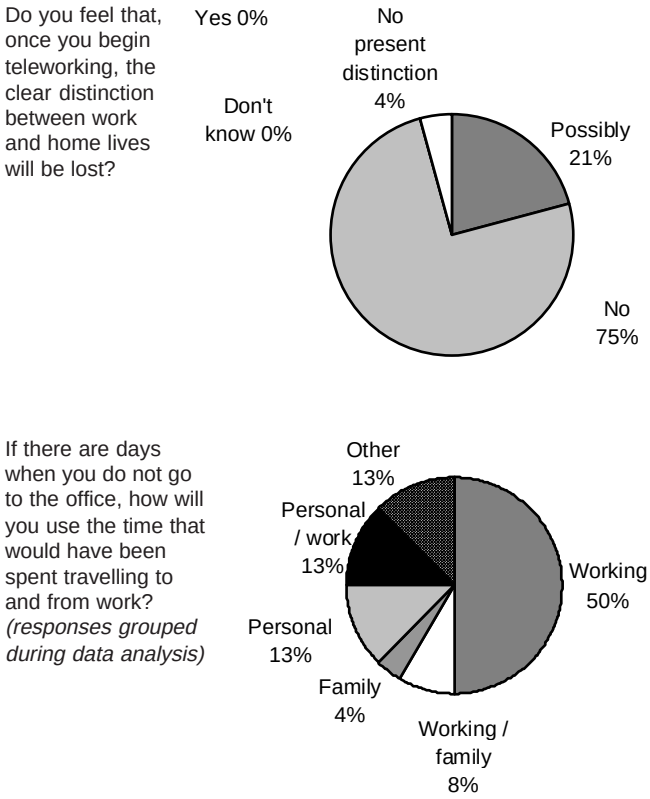


Figure 3 Attitudes to teleworking before the trial

2.3.2.3 Perceived benefits before the teleworking trial

The motivation to telework was not expected to arise from parking difficulties at the (traditional) workplace - 96 per cent of participants could readily park their car at work, regardless of the time of arrival.

It appeared likely that the number of new car journeys resulting from the availability of the work vehicle would be limited. The majority (87 per cent) of participants did not consider that their work vehicle would be used by other members of their household while they were teleworking. Two-thirds of these indicated that this was because the other household members who were eligible to drive had their own cars.

None of the participants had their work progress closely monitored. This suggests that they were all in a position where their work was judged by what they delivered and were therefore considered responsible enough to organise and conduct their own work. Correspondingly virtually none of the participants (4 per cent) were concerned that their boss would not be able to see them working at home.

Nearly half (46 per cent) of participants expected that spending more time away from the office would make their job easier, largely on the grounds of reduced distraction and interruption. Some felt the job would be made harder in terms of organisation and communication difficulties. When asked about how the productivity of fellow team members would be affected by the participant's absence from the office, 63 per cent of participants anticipated that there would be little or no effect.

Nearly three quarters (71 per cent) of participants said they were not concerned by the prospect of a reduction in the amount of informal or social interactions with work colleagues. However, 46 per cent of these indicated that they would be concerned if the frequency of teleworking they intended to do were to increase. While only 17 per cent of participants indicated their intention to telework only one day per week, there were clear implications that a number of others would be adopting a similar policy.

Only one participant had attended a workshop or course on teleworking.

Motivations to telework appeared to be principally driven by the desire to make use of a more suitable working environment and to take advantage of increased flexibility as shown in Figure 4. This was expected to lead to an increase in productivity and efficiency, in conjunction with increasing the opportunity to participate in family activities. Two participants wished to experience and explore what they saw as a future working practice. Financial savings and environmental benefits were not major motivations.

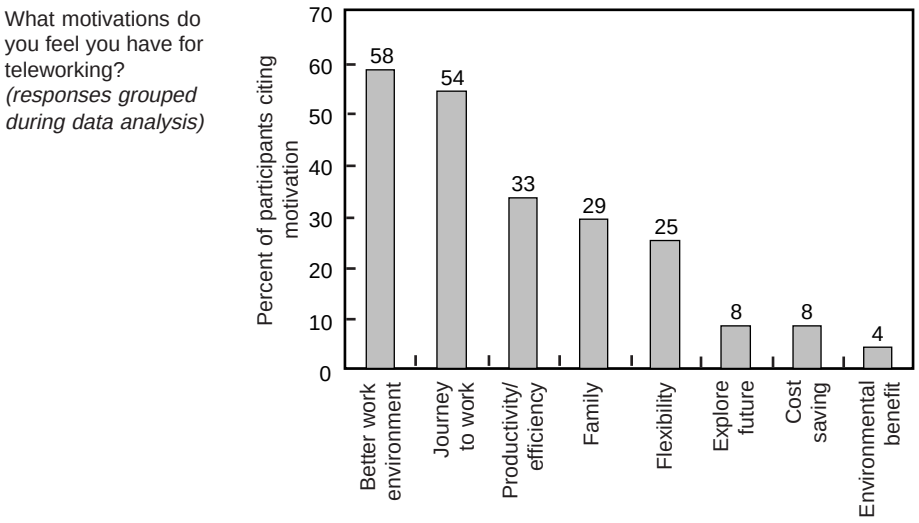


Figure 4 Motives for teleworking

Two fifths (42 per cent) of participants envisaged making a financial saving from teleworking. None of the participants from the AA expected a financial saving to be made, perhaps unsurprisingly, since they all had a company car. Some participants expected to make a substantial financial saving:

> *'I should save £100 per month on petrol alone, I'd estimate'.*

A fifth (21 per cent) of participants considered that some or all of the travel cost savings would be countered by an increase in domestic expenditure (heating, telephone, etc.).

The main perceived disbenefit of teleworking was the remoteness from colleagues (Figure 5), although the earlier observation that 71 per cent of participants were not concerned by a reduction in interaction with colleagues suggests that the significance of this disbenefit is limited.

The main benefits to the employer perceived by the participants were improved employee productivity and efficiency, and the reduced need for office space (Figure 6). A minority (17 per cent) of participants saw no disbenefits for their employer. The only clear disbenefit was the lack of easy or instant availability of the teleworker (identified by 29 per cent of the participants). There was also an awareness that management and working practices would need to adjust to accommodate teleworking.

2.3.3 Summary

Despite the small sample size a number of salient points emerged from the interviews. The main motivations for teleworking from the sample were to have a work environment which is more conducive to sustained concentration without interruption (58 per cent of sample), to avoid undesirable factors relating to the journey to/from work (54 per cent), to improve personal productivity/ efficiency (33 per cent), to improve the opportunity to be more involved with family activities (29 per cent) and to achieve increased flexibility (25 per cent). The main disbenefits were seen to be being remote from colleagues and the risk of the distinction between home and work becoming more blurred.

Prior to the study two-thirds of the sample had considered working from home quite seriously. Nearly a third (29 per cent) expressed a clear objective to keep weekends 'work-free'. Increased substitution of weekend work for weekday work and vice versa was envisaged, reflecting the expectation that improved efficiency would allow greater control over the total number of hours worked.

A number of significant points were relevant to travel. Over half (58 per cent) of the sample anticipated (either through choice or obligation) that they would telework for part-days at least sometimes. This suggested that the potential to reduce vehicle miles travelled (due to the commute journey) by teleworking would be diminished. Parking problems at work provided no incentive to work at home as 96 per cent of the sample could readily park at work regardless of the time of day.

An increased number of non-work journeys made by other household members appeared unlikely; the majority (87 per cent) of the sample indicated that when teleworking the travel-to-work vehicle would not be used by other household members. In many cases other household members with a driving licence had their own vehicle. A large proportion (71 per cent) of the sample expected to use some or all of the saved commute travel time for working, though not necessarily to increase their total hours worked.

The main benefits of teleworking for the employer were perceived by the sample to be improved employee productivity / efficiency, a reduced demand on office space and an improvement in employee health and morale.

2.4 Self-completed record of daily travel

2.4.1 Introduction

Participants were asked to complete a daily record of their travel. This was done in two parts: a travel diary to record

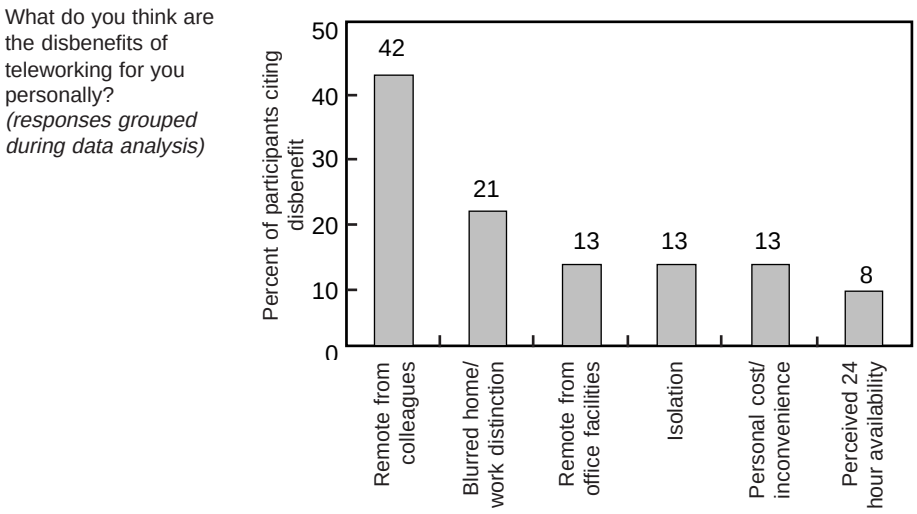


Figure 5 The perceived disbenefits of teleworking

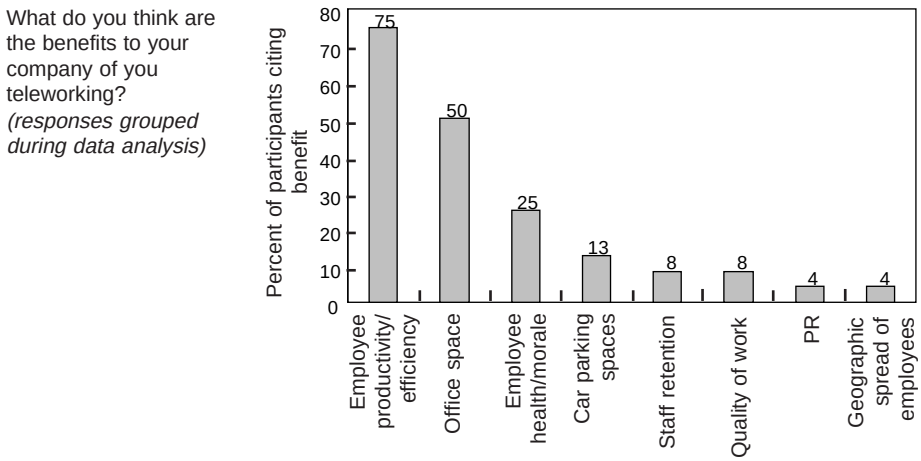


Figure 6 The perceived benefits for employers

their journeys, whether by car or any other mode, and a vehicle log to record journeys made in their vehicle, irrespective of whether it was they who were using it. The aim was to gather a comprehensive record of travel patterns of the individual, and also to assess the use of transport within the household. From the logs returned a database of over 2000 journeys was compiled.

2.4.2 Results

The travel characteristics of participants varied widely. Figure 7 illustrates the diversity in the number of journeys made and distances travelled during the four weeks. Eight of the participants each covered over 2,000 miles in the four weeks of survey, but the number of journeys made within this varies from 74 to 146. Four participants covered less than 1000 miles, but again with a wide range in the number of journeys undertaken.

The main focus of the study was on journeys made to work and in the course of work; which were most likely to change after the start of teleworking. Table 8 shows the number of journeys made, together with mean distance. Approximately 30 per cent of all journeys were made either to work or in the course of work. These journeys tended also to be above average in length: 21.4 miles for work journeys, compared with 17.3 miles for other journeys. The proportion of mileage on work journeys averaged 36 per cent, but was as high as 50 per cent for a number of people, including most of those at the BBC. There were differences between the organisations in journey lengths, but the number of participants involved was not sufficient to make the difference significant.

A slightly different perspective is shown by Table 9, where mean start and arrival times are shown. The differences between organisations perhaps reflected the different ways in which they work. Comparisons will be more meaningful in the ‘after’ stage under teleworking conditions. A distinction between this table and Table 8 is that the journeys in Table 9 relate to the travel-to-work vehicle; these are journeys that may not necessarily have been undertaken by the participant. Other members of the household may have used the vehicle. Such opportunities may have increased with teleworking.

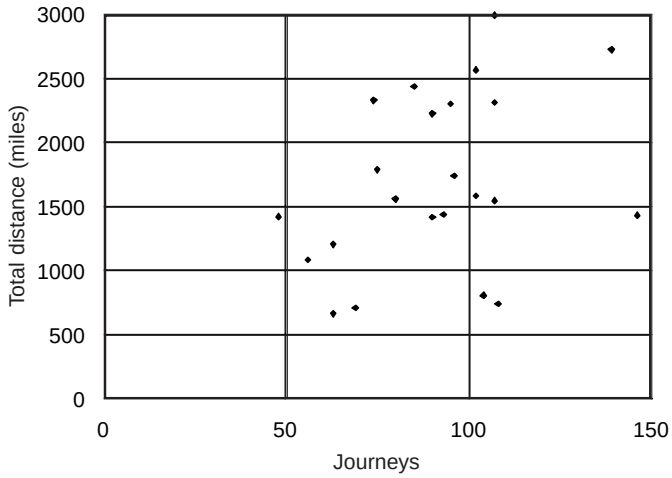


Figure 7 Number of journeys and distances travelled by participants

Table 8 Purpose of journeys made by participants

	Journeys to, from, or in the course of work	*Mean distance*	*Other journeys*	*Mean distance*	*All journeys*	*Mean distance*
AA	182	23.6	417	18.4	599	20.0
BBC	211	27.0	333	15.6	544	20.0
HCC	59	12.2	140	10.4	199	10.9
G&P	197	18.8	565	18.7	762	18.7
Total	649	21.4	1455	17.3	2104	18.5

Table 9 Journeys made in the travel-to-work vehicle

	Work purposes				*All purposes*	
	Journeys	*Mean start*	*Mean arrival*	*Mean distance*	*Journeys*	*Mean distance*
AA	177	10:03	10:39	23.8	535	21.0
BBC	153	10:17	10:59	21.4	420	17.3
G&P	150	09:20	09:50	21.0	545	16.7
HCC	59	09:28	09:49	12.2	213	11.2

A further analysis of the work journeys undertaken by participants is shown in Table 10. This shows the mean start and arrival times for work journeys on each day of the week, together with mean distance. These include journeys in the course of work, as well as journeys to work, which explains why start times were on average later than those for journeys to work shown in Table 3. Some participants made work journeys on Saturdays and Sundays, as expected from the interviews.

In Table 11 the number of journeys made to work on each day of the week is shown. This gives an indication of the average times at which journeys were made, and the use of motorways in those journeys. Journeys on weekdays started around 08:00 on average, with arrival times averaging between 08:30 and 09:00. Distances averaged around 20 - 22 miles and over half of the distance was on motorways. The pattern at weekends was rather different, with later start times and shorter distances and durations.

Table 10 Work-related journeys made by participants

Day	*Mean start time*	*Mean arrival time*	*Distance (miles)*
Monday	10:04	10:38	20.9
Tuesday	10:00	10:34	19.3
Wednesday	10:11	10:48	21.1
Thursday	10:16	10:52	22.7
Friday	09:53	10:32	22.0
Saturday	14:30	15:28	38.7
Sunday	09:52	10:33	30.7

Table 11 Journeys to work by day of week

Day	*Journeys*	*Mean start*	*Mean arrival*	*Mean distance*	*Motor -ways %*
Monday	55	7.52	8.27	22.8	57.9
Tuesday	57	8.13	8.54	23.6	63.1
Wednesday	58	8.10	8.44	20.1	57.1
Thursday	63	7.56	8.31	22.0	59.9
Friday	55	8.10	8.44	22.5	61.1
Saturday	2	10.38	10.58	11.5	15.0
Sunday	4	10.50	11.21	20.2	23.8
Total	294	8.07	8.43	22.1	58.9

Further details of individual travel patterns are shown in Table 12, where analysis from the vehicle logs is shown. The table shows the use made by each participant of the travel-to-work vehicle, and also the use made by others. Almost all of the journeys (95 per cent) and of the distance travelled in these vehicles were made by the main driver. There were some small differences in vehicle use: 'main driver' journeys were fractionally longer, involved more motorway driving, and had fewer passengers. On average, about half the journeys made by teleworkers in their travel-to-work vehicle included a passenger, but this depended to some extent on whether the vehicle was a company car.

2.4.3 Summary

There was a wide range in the mileage driven by the participants: in the four week period some participants totalled nearly 3000 miles - equivalent to around 35,000 miles on an annual basis. In some cases this resulted from a high frequency of journeys, while in others it was due to a high mean distance for each journey.

Differences were also apparent in the use made of the main travel-to-work vehicle. For most participants all journeys made in the travel-to-work vehicle were made by the teleworker, while in seven cases other household members also used the vehicle. None of the AA participants exhibited a difference in journeys, probably because their vehicles were company cars and were therefore likely to be used differently.

Large variations were also seen in both the number of passengers carried and the use of motorways. The average number of passengers was 0.40 per journey for all journeys, but two participants had no passengers for any journeys and one participant averaged 1.13 passengers per journey. These figures indicate particular journey

Table 12 Journeys made in the travel-to-work vehicle in four week period

	All journeys					*Journeys by main driver*				
Subject no.	*No. of journeys*	*Total distance (miles)*	*Mean distance*	*Motor -ways %*	*No. of pass.*	*No. of journeys*	*Total distance*	*Mean distance*	*Motor -ways %*	*No. of pass*
1	89	2174	24.4	41.2	0.38	89	2174	24.4	41.2	0.38
2	88	1677	19.1	28.1	0.53	88	1677	19.1	28.1	0.53
3	107	2306	21.6	44.3	0.92	107	2306	21.6	44.3	0.92
4	96	1463	15.2	46.5	0.45	96	1463	15.2	46.5	0.45
5	55	1071	19.5	48.9	0.16	55	1071	19.5	48.9	0.16
6	100	2551	25.5	35.6	0.07	100	2551	25.5	35.6	0.07
7	89	2552	28.7	42.5	0.40	85	2539	29.9	44.5	0.39
8	95	1206	12.7	33.7	0.40	95	1206	12.7	33.7	0.40
9	113	938	8.3	13.3	1.13	111	909	8.2	12.8	1.12
10	50	2040	40.8	62.0	0.28	50	2040	40.8	62.0	0.28
11	82	610	7.4	43.0	0.13	77	383	5.0	40.9	0.08
12	72	1129	15.7	41.0	0.13	72	1129	7.4	41.0	0.13
13	44	637	14.5	41.8	0.39	44	637	15.7	41.8	0.39
14	73	1486	20.4	58.3	0.64	73	1486	14.5	58.3	0.64
15	72	443	6.2	10.9	0.31	46	362	7.9	10.2	0.43
16	69	1784	25.9	26.0	0.36	69	1784	25.9	26.0	0.36
17	74	1287	17.4	12.2	0.31	70	1088	15.5	15.8	0.29
18	35	510	14.6	22.4	0.34	35	510	14.6	22.4	0.34
19	56	1101	19.7	20.5	0.39	56	1101	19.7	20.5	0.39
20	6	233	38.8	57.5	0.00	6	233	38.8	57.5	0.00
21	35	426	12.2	75.8	0.00	35	426	12.2	75.8	0.00
22	93	1574	16.9	28.3	0.65	79	1513	19.2	32.6	0.67
23	120	802	6.7	12.5	0.87	95	622	6.6	12.0	0.52
24	96	1021	10.6	42.8	0.34	96	1021	10.6	42.8	0.34
Total	1809	31,003	17.1	34.4	0.46	1728	30,216	17.5	35.2	0.44

Source: Vehicle Log

characteristics such as regular journey-sharing. With a standard deviation of 0.3 (74 per cent of the mean) there was a wide variation between participants.

The use of motorways also showed some variation. Motorway use is to an extent determined by location of origins and destinations, but it does have an implication for use of energy and environmental impacts because of the higher mean speeds and smoother driving patterns on motorways. On average motorways were used for 38 per cent of total distance for all journeys, with a range between 11 per cent and 76 per cent. The total distance driven on motorways ranged between 48 and 1265 miles in the four week period.

3 'After' survey

3.1 Introduction

The 'after' survey involved a number of elements:

- vehicle logs and travel diaries for each participant to complete;
- interview and questionnaire for each participant;
- employer and colleague questionnaires;
- a study of established teleworkers.

The surveys provided a broad base of information from which a comprehensive assessment of teleworking could be made. Twenty-four participants were surveyed in the 'after' phase, although not everyone completed the vehicle logs and travel diaries to the same extent. This has been taken into account in the following analyses.

3.1.1 Vehicle logs and travel diaries

Vehicle logs and travel diaries were completed for a series of seven-day periods during the course of the teleworking trial. At approximately monthly intervals a 7-day period was identified in which teleworkers expected to have the *opportunity* to telework (i.e. circumstances such as periods of leave were deliberately avoided). This enabled a limited longitudinal profile of travel behaviour to be recorded during a period in which participants would be becoming accustomed to teleworking, which for some may have entailed major changes in lifestyle and travel patterns. The analysis compared days with and without teleworking during these survey periods.

3.1.2 Teleworker interview and questionnaire

These surveys took the same form as those conducted in the 'before' survey. A substantial proportion of the questions were common to the 'before' and 'after' survey (and/or the studies of established teleworkers - see Section 3.1.4) and were intended to clearly identify changes in behaviour or attitude. Responses to such questions are reported directly in Section 3.3.5 and Section 3.4.

3.1.3 Employer and colleague questionnaires

Ultimately the employer will have the power to determine the policy on working practices and whether or not to support teleworking in this context. Employers' representatives were therefore given a short mail-back questionnaire to complete reflecting their response to the trial. A change in working practice for the teleworkers is likely to influence the working practices of colleagues and may or may not serve to offset some of the benefits accrued by the teleworkers, so colleagues were also given a short mail-back questionnaire to complete.

3.1.4 Studies of established teleworkers

To provide a comparison with the findings from the teleworking trial a parallel, 'retrospective' study of established teleworkers was conducted. The objective was to extend certain aspects of the longitudinal profile obtained during the trial to determine how and if behaviour and attitudes would change in the longer term. The intention was to recruit people who had teleworked for between one and three years, but the final sample had teleworked for between two and four years. A sample of established teleworkers was identified that broadly matched the profile of those taking part in the trial. The sample consisted of employees who worked at home for part of their working week. A mail-back questionnaire was sent to each established teleworker, with many of the questions common to those in the 'after' survey.

Most of the established teleworkers in the study worked for IBM (16), and there was one employee at each of three other organisations: Hampshire County Council, Wessex Translations and Technodyne Ltd. There were 4 who had been teleworking for 2 years, 6 who had teleworked for 3 years and the remaining 9 had teleworked for 4 years. Their jobs were more IT oriented than those of the main sample, with 3 describing their jobs as manager/director, 5 as communications/system/ IT specialist and 11 as technical writer/ checker/ information developer.

3.2 Frequency of teleworking

The average frequency of teleworking per week in the trial was 1.2 days. This compared with 1.7 for the more established teleworkers. The difference between the two groups might be explained in part by the stronger emphasis on IT in the established group, which may lend itself more readily to teleworking than some of the occupations in the main sample. However there was also evidence that the frequency of teleworking might increase over time as habits become established. Within the established group those who had been teleworking for 4 years teleworked for 2.1 days per week on average, compared with 1.8 and 1.2 days for those who had teleworked for 2 and 3 years respectively.

3.3 Vehicle-related factors

3.3.1 Journey patterns

The main focus of the study was to monitor activity during the week when teleworking was potentially a direct replacement for working in the office. There was a total of 449 survey days recorded in the 'before' period on Mondays to Fridays. The number of weekdays recorded in the 'after' phase where teleworking did not take place was 327, while there were 94 days when teleworking did take place, on Mondays to Fridays. The reduction in the number of days surveyed in the 'after' phase compared with the number of days surveyed in the 'before' phase was due to differing response rates from participants and the fact that the 'after' phase was conducted over a much longer time span which affected rates of completing records. This meant that all analysis was in terms of rates per week or per day, to standardise for the difference in recording periods.

The frequency of travel and the distances covered by the participants of the main trial on weekdays are summarised in Table 13. The table shows that the frequency of travel for commuting averaged 1.5 journeys per day in the 'before' survey and 1.4 on non-teleworking days in the 'after' study. It might have been expected that the number of commute journeys would be about 2 per day; the difference is explained by journeys in the course of work, which in some cases were made instead of commuting journeys.

Table 13 Summary of all journeys and distances (Monday to Friday) for participants of the main trial

Survey		*Commute*	*Work -related*	*Other*	*Total*
'before' (449 days)	Journeys/day	1.5	0.8	1.4	3.6
	Miles/day	32.0	14.8	27.7	74.5
'after' - Non-teleworking days (327 days)	Journeys/day	1.4	0.7	1.2	3.3
	Miles/day	30.1	15.6	15.4	61.1
'after'- Teleworking days (94 days)	Journeys/day	0.2	0.2	0.8	1.2
	Miles/day	4.8*	3.5	7.6	15.9

Source: Travel Diary

** includes journeys that may have been made from home to work on 'work' purpose*

The results in Table 13 show some changes upon the introduction of teleworking. There was also some indication of changes in travel behaviour when teleworking was not taking place. In the 'before' phase each participant travelled an average of 74.5 miles each day (by all modes). In the 'after' phase there was a reduction to 61.1 miles/day on non-teleworking days, while on teleworking days just 15.9 miles per day were travelled. In the 'after' phase there was a small decline in travel activity on non-teleworking days with a reduction in average journey-making from 3.6 to 3.3 journeys per day. On teleworking days just 1.2 journeys were made on average each day, with an average length of 13.0 miles, suggesting a large change not only in journey frequency but also in journey purpose.

These changes were by no means uniform, and some variation existed across the participant sample. The changes noted on non-teleworking days in the 'after'

phase did not occur evenly: daily mileage declined for only two-thirds of the sample; while about half had a reduction in the length of journey. Two-thirds made fewer journeys per day. The picture was much more clear cut on teleworking days, with only three participants making journeys which were on average longer, and one making more journeys per day.

Teleworking was used exclusively as a substitute for weekday commuting with no teleworking days recorded at weekends. Table 14 indicates a small amount of travel to work or on work-related journeys at weekends but none of these were made on teleworking days. This concurs with the 'before' survey findings that only 4 per cent of the participants did some work every weekend while 58 per cent worked at weekends only once or twice a month. There is therefore no evidence from the trial to indicate that teleworking caused any shift of commute journeys from weekdays to weekends or that weekend commute journeys were removed by teleworking.

Table 14 Average number of journeys per day per teleworker at weekends

Survey	*Commute*	*Work -related*	*Other*	*Total*
'before'	0.1	0.1	3.6	3.8
'after' – non-teleworking days	0.1	0.9	3.0	4.0
'after' – teleworking days	-	-	-	-

Source: Travel Diary

3.3.2 Modal split

The above analysis indicates that there was some change in behaviour brought about by teleworking, and not just on days when teleworking took place. The main evaluation focuses on weekday travel, but it was important to assess the implications for travel, the environment and energy consumption by looking separately at each mode of transport on all days of the week. In the analysis a total of twelve modes was identified, these are outlined in Table 15 which shows travel on all days of the week.

As would be expected given the high levels of car ownership and driving licence holding, the vast majority of travel was made by private car - over 80 per cent of journeys and total distance in all three parts of the survey. Within this picture though there were some small variations, which might be important if teleworking were adopted more widely. These are associated with the use of pool cars and trains.

Table 15 shows whilst the proportion of total daily mileage by train, cycle and foot was higher during a teleworking day, the values themselves actually decreased. This increase in the proportion of mileage was mainly as a result of a reduction in the use of other motorised modes of transport.

Cycling was the only mode where the mean distance of journeys increased appreciably (i.e. doubled) during a teleworking day.

The use of pool cars also appears to have changed. Twenty-seven journeys were conducted by this mode in the 'before' phase, 14 on non-teleworking days, but none on teleworking days. This change in behaviour is hardly surprising, given the impracticality of obtaining pool cars at home.

3.3.3 Journeys undertaken by private/pool car

From the analysis of modal split it is clear that the predominant mode of travel was the private or pool car. In the 'after' phase it was important to assess this closely as the application aimed to reduce the extent of such travel. This section shows the nature of private/pool car travel on teleworking days, and how it compared to non-teleworking days.

Table 16 shows the extent of weekday travel by 'main driver', taken from the vehicle logs. The resulting patterns show some similarity to Table 13, but with an even more marked reduction in car travel on teleworking days compared with non-teleworking days.

The average distance driven as the main driver in the 'before' phase was 57 miles per day. The mean journey length was 19.1 miles. In the 'after' phase on non-teleworking days there was a small reduction to 53 miles per day, with an average of 17.5 miles per journey. This difference in mileage between the 'before' phase and the non-teleworking days in the 'after' phase was not statistically significant at the 95% level, although with a larger sample of participants or a longer monitoring period, a significant difference might have been observed. On teleworking days, however, the mean distance driven each day was only 7.7 miles. Two changes contributed to this: there was a reduction in mean journey length of 30 per cent and also a reduction in journey frequency of 79 per cent. On teleworking days the average number of vehicle journeys per day was 0.6, compared to 3.0 journeys per day in the 'before' phase.

In the sample as a whole, a similar pattern emerged to the one identified for all modes with a mix of responses on non-teleworking days in the 'after' phase, but a clear response on teleworking days. On the measures of miles/day, journeys/day and mean journey length roughly half of the participants experienced increases and half decreases when not teleworking. When teleworking there was a much clearer response, with the only increases being four participants whose mean journey length increased.

3.3.4 Further journey characteristics

Apart from journey characteristics such as number, length and frequency, there are further statistics that give an indication of behavioural patterns. In the vehicle logs the participants were asked to record the number of passengers on each journey and the percentage of motorway use on that journey. The previous analyses show some of the impacts of teleworking, but in this section some more background can be given.

In the 'before' survey the mean number of passengers per journey (Monday to Friday) was 0.22. In the 'after' phase the figure rose slightly on non-teleworking days to 0.28. With standard deviations larger than the mean values there is little difference between these two figures. Looking at the trial participants, nine carried more

Table 15 Modal split and distance travelled: all days

		Before		*After - non teleworking days*		*After- teleworking days*	
			% of total		*% of total*		*% of total*
Own car	Miles/day	56.06	82.7	49.03	89.8	11.52	79.3
	Mean dist	17.9		16.4		12.0	
	Journeys/day	3.13	84.2	2.99	92.3	0.96	86.1
Other private car	Miles/day	2.42	3.6	0.79	1.4	0.31	2.1
	Mean dist	11.2		10.1		8.0	
	Journeys/day	0.22	5.8	0.08	2.4	0.04	3.5
Pool car	Miles/day	1.56	2.3	1.16	2.1	0	0.0
	Mean dist	34.3		37.0		0.0	
	Journeys/day	0.05	1.2	0.03	1.0	0	0.0
Train	Miles/day	5.64	8.3	2.72	5.0	2.49	17.1
	Mean dist	56.6		50.5		42.7	
	Journeys/day	0.10	2.7	0.05	1.7	0.06	5.2
Lorry/ coach/ bus	Miles/day	0.65	1.0	0	0	0	0
	Mean dist	11.4		0		0	
	Journeys/day	0.06	1.5	0	0	0	0
Taxi	Miles/day	0.20	0.3	0.14	0.3	0	0.0
	Mean dist	10.7		10.2		0	
	Journeys/day	0.02	0.5	0.01	0.4	0	0.0
Cycle	Miles/day	0.14	0.2	0.14	0.3	0.10	0.7
	Mean dist	4.8		7.6		10.0	
	Journeys/day	0.03	0.8	0.02	0.6	0.01	0.9
Foot	Miles/day	0.27	0.4	0.11	0.2	0.13	0.8
	Mean dist	2.3		2.1		2.5	
	Journeys/day	0.11	3.0	0.05	1.6	0.05	4.3
Boat	Miles/day	0.01	0.0	0.27	0.5	0	0.0
	Mean dist	2.3		120		0	
	Journeys/day	0.01	0.1	0.002	0.1	0	0.0
Air	Miles/day	0.83	1.2	0.27	0.5	0	0.0
	Mean dist	245		120		0	
	Journeys/day	0.003	0.1	0.002	0.1	0	0.0
Total	Miles/day	67.78	100	55	100	14.54	100
	Mean dist	18.3		16.8		13.0	
	Journeys/day	3.71	100	3.24	100	1.12	100

Source: Travel Diary

Table 16 Summary of 'main driver' journeys (Monday to Friday)

Survey		*Commute*	*Work -related*	*Other*	*Total*
'before' (449 days)	Journeys/day	1.3	0.6	1.0	3.0
	Miles/day	29.3	11.2	16.1	56.6
'after' - Non-teleworking days (327 days)	Journeys/day	1.4	0.6	1.1	3.0
	Miles/day	29.6	11.0	12.2	52.8
'after'- Teleworking days (94 days)	Journeys/day	0.1	0.1	0.4	0.6
	Miles/day	2.6	1.3	3.7	7.7

Source: Vehicle Log

passengers, eight carried less, and seven saw no change. On days when teleworking did take place there was a slightly more marked change. Although there was an increase to 0.44 passengers per journey, this did not suggest a wholesale change in behaviour. Nine of them carried more passengers, but eleven carried less. The standard deviation is also very large (0.58), indicating some divergence in patterns.

A change in the use of motorways following teleworking might indicate a change in working patterns and general travel behaviour. All the participants used motorways to some extent; in the 'before' study participants used motorways for approximately 43% of their mileage. In the 'after' phase this rose to 50% on non-teleworking days, but was only 24% on teleworking days. These effects were not all felt evenly. On non-teleworking days 16 participants used the motorways more, while on

teleworking days 18 used them less. Of the five that used the motorways more, three also used them more on non-teleworking days. These variations indicate that most participants changed their travel behaviour on teleworking days such that they used the motorways less, but some participants actually used the motorways more. This change in motorway use indicates some localisation of activities and journeys.

3.3.5 Behavioural background to changes in journey patterns

Interview and questionnaire data can be used to interpret some of the changes in travel. Over half (52 per cent) of the trial teleworkers said their home was nearer than the workplace to some places visited during the course of their work. Of those six indicated that they had positively exploited this in terms changing their journey patterns - e.g.:

> *'Particularly when travelling to London, I'll not go to Southampton to catch the train, but go to a station that's more convenient for me. That's also a cost and time saving'.*

In the study of established teleworkers only one person made such changes (an 'opportunity manager'). The difference may be explained by the nature of the work being carried out by the teleworkers in the more established group. Almost all were concerned with IT development and therefore may have had less reason to make visits in the course of work.

Within existing teleworking literature the effect on public transport of teleworking is tentatively considered. If teleworkers begin travelling within the suburbs and interacting with other teleworkers then they will not be making the more conventional suburb to centre or centre to suburb work journeys upon which most public transport systems are founded. Such journeys will not therefore be able to be serviced by public transport. One comment from the trial drew attention to the practice of inter-teleworker journeys:

> *'Whether teleworking is succeeding or failing is a matter of sensible expectations. It can be a very positive thing, but it has limited benefits. We really couldn't do it for more than twenty per cent of the time. Also, once a teleworking colleague came round to my house and we worked together for a day.'*

Trial and established teleworkers were asked whether in a house move they would be more likely to live further away from their workplace than if they were not teleworking. This question provoked a mixed response with no clear indication of the magnitude of the implications from the responses. Nonetheless 26 per cent considered it would influence any future house move decision. Three people, having indicated either 'no' or 'don't know', said teleworking would have a permissive role rather than a deterministic role in any such house move (as in review literature):

> *'Not necessarily, but it would give me the option. It would make my family more flexible. For example if my husband were to get a new job, it would make the circle of where we could live a bit larger, say if I lived 40 miles away and came in two times a week - that's possible - but if I had to come in every day it wouldn't be. I wouldn't choose to live further away.'*
>
> *'.... not more likely but it would be more possible.'*
>
> *'At the moment we may buy our home, we may not, and we're very settled. At the moment teleworking is just a trial. If it becomes permanent, it might become a factor, but I don't think it would be top of the list.'*

In contradiction to this one person indicated that:

> *'I'd have a wider range of choice of location for my private life, because commuting to work would be a less significant factor. In fact, it's something we've discussed at some length.'*

A higher proportion of established teleworkers felt that they might live further away. In fact two had already put this into practice:

> *'I do live 100 miles from the office - I couldn't manage that if I wasn't teleworking'* (3 days/week telework).
>
> *'Have already moved to more desirable area further away from work'* (2 days/week telework).

3.4 Working practices

As a working practice teleworking must deliver a net benefit to an organisation for it to be a viable option. Only through increasing adoption levels will teleworking serve to increase the magnitude of the energy and environmental impacts of teleworking. Uptake issues are discussed in Section 4.2, which includes some discussion concerning working practices and the perceived benefits and disbenefits to the employer, from the teleworker's perspective.

As Section 4.4 will show, teleworkers believe that teleworking will deliver the benefits of improved productivity and efficiency. This is attributed in part to the reduced stress and improved morale of the teleworkers. Flexibility was frequently mentioned by the trial teleworkers as a benefit. In particular 83 per cent of trial teleworkers indicated that teleworking took place at times of day when the teleworker would not normally have been working in the office. This was the case for four of the five AA teleworkers who reasoned that they did not have to travel into work. A further two teleworkers responded likewise. Four teleworkers indicated reasons relating to time-shifting of work, i.e. a more flexible lifestyle:

> *'I've done things like see my kid's school assemblies, things that I've never been able to do before, by time-shifting the work.'*

'I was very disciplined. I started between 8.30am and 9am and I did the number of hours I would have done had I been in the office. One advantage, particularly in the summer months, I could get an extra half hour's fishing in.'

When asked whether motivation to work had increased as a consequence of teleworking a substantial proportion of the respondents found their motivation did not change. The 35 per cent of respondents prior to the trial, who were either uncertain about motivation or thought teleworking would increase their motivation, found their motivation to work did not change. Comments were typified by the belief that they were already motivated or that they wanted to be careful to use teleworking to their advantage:

'I think it has made it pleasanter and more convenient, but I can't honestly say I want to do more of it [work].'

'I think I've always been motivated to meet deadlines. Possibly teleworking made that easier, but that is offset by a desire to demonstrate how productive teleworking can be.'

Asked how the saved commuting time was used, 78 per cent said they worked for all or part of that time. This was similar to the proportion in the 'before' survey who had expected to do this. Eleven of the trial teleworkers had children under 13 years old; six of these spent all or some of the saved time with their family; this was rather more than had been expecting to do so in the 'before' survey. Five teleworkers spent all or some of the time relaxing.

A key characteristic of teleworking is being remote from the normal place of work, which in turn raises the issue of communicating with colleagues. For communicating with the office 48 per cent of trial teleworkers used only a phone and/or fax. The remaining 52 per cent also had access to Email. Half of the teleworkers used the telephone less often when teleworking (22 per cent used it the same amount). This concurs with the benefit seen by many teleworkers of securing uninterrupted time at home to work. However, five of the eight BBC teleworkers used the telephone more frequently.

Half found that informal or social interaction with colleagues was not affected by teleworking (all of those at the AA found this, 5 of those at Gifford and Partners found this), but half found that there was not as much informal or social interaction with work colleagues while teleworking (all of those at the BBC, and 2 of the 3 at HCC). Only two people were adversely affected by this:

'I hated it. It made me depressed and lonely, and I had an overwhelming desire to come to work. I missed the ability to discuss things with colleagues, and I greatly missed lunching, sitting chatting, having a laugh.' (This person does not want to continue to telework)

'I was glad to be back at work the following day.'

A fifth made comments to the effect that it was not a problem because they were only part-time teleworking. Similar feedback was received from the established teleworkers. A minority felt isolated, but again the issue of isolation was reconciled by the part-time nature of the teleworking:

'I don't think I'm at home enough to seriously affect this, although I'm sure that I'd be more of an 'outsider' if I worked from home more than two days per week.'

More of the teleworkers found that their job had been made easier (61 per cent) than had expected this to be the case in the 'before' survey (44 per cent). No-one in the trial found that teleworking had simply made their job harder. For 17 per cent it had been harder in some respects; there was a need for greater communication, interaction and planning.

Of significance to the travel impacts of teleworking is whether people telework for a full day. Teleworking for part of a day can result in the commute journey still being made which negates one of the principal benefits of teleworking.

Figure 8 indicates the proportions of teleworkers who expected to or did telework part days.

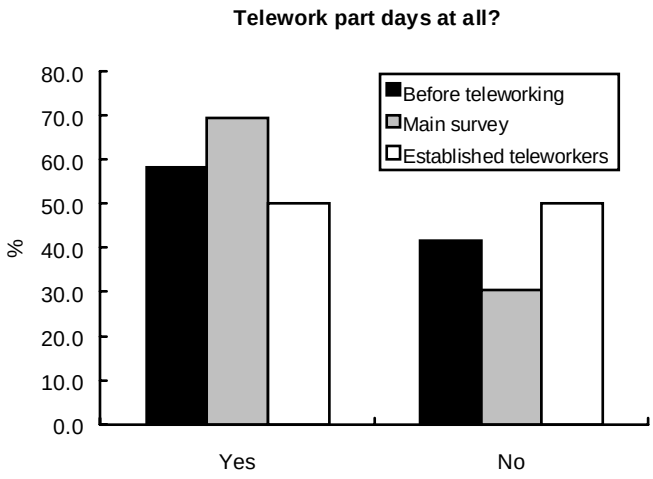


Figure 8 Teleworking part days

Comparison between the 'before' and the 'after' survey shows that the proportion of people who had teleworked for some part days was rather higher than the proportion who had expected to do this. Almost 70 per cent of the teleworkers in the trial teleworked part days sometimes. Of these, 44 per cent specifically mentioned the need to attend meetings as one reason. One inference that can be made from this is that management staff are more likely to telework yet are also most likely to have meetings and consequently only telework part days thereby diminishing the potential benefits of teleworking. All the BBC participants teleworked part days, principally on location filming.

The main reason given for not teleworking part days was the commute distance involved. In general those

teleworking part days had tried to avoid so doing. With the need to adjust to this different style of working the rearrangement of schedules would become more effective over a longer period, perhaps reducing the amount of part day teleworking.

The causes of part day teleworking were not always related to a visit to the office. Teleworkers classed themselves as teleworking part days even if a meeting was with a client. In this sense the commute journey was saved but a journey in the course of work was made (four teleworkers indicated that this had been the case). Several people pointed out that teleworking part days was not a regular practice: '*not very often*', '*sometimes, but not as a rule*'. Four people mentioned stopping teleworking on occasions where some business had to be conducted elsewhere but not necessarily at the office.

3.5 Teleworkers' colleagues

A total of 16 colleagues responded to the questionnaire. Some responses were incomplete but all are included in the analysis. Reported results indicate the corresponding number of responses to individual questions.

The specification of what constituted a colleague was not restrictive, but teleworkers and employers were encouraged to identify individuals who had a working relationship and interaction with the teleworker. From the 16 responses, seven colleagues were either an assistant or secretary of the teleworker. Other positions included deputy, section worker or fellow member of department/section.

Figure 9 summarises the frequency of teleworking as perceived by the colleagues. The average of 1.6 days per week is slightly higher than the value of 1.2 obtained from the teleworkers themselves. This may be due to the 8 colleagues who did not respond coupled with the interpretation of part-day teleworking. The majority (15) reported that their teleworker colleagues did not telework on the same day each week. Three quarters (12) of colleagues were informed when the respective teleworker would be teleworking each week.

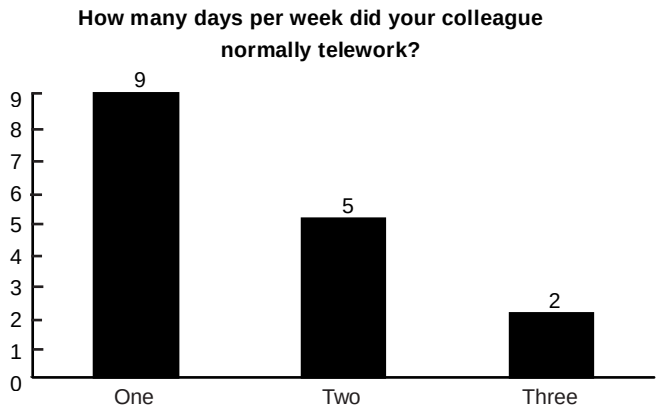


Figure 9 Frequency of teleworking

Before the teleworking trial, three-quarters (12) of the colleagues had face-to-face contact with the respective teleworker more than once per day. The remaining colleagues had such contact at least once or twice a week. Half of colleagues found that this level of contact did not change once teleworking had begun; 38 per cent found it decreased and 13 per cent found it increased. Half found that there had been no change in their working relationship in the time their colleague had been teleworking. The other half all indicated an improvement in the relationship:

'Easier communication. Eliciting information often difficult; telework has offered us a less threatening way of asking for information we require.'

'More consideration from teleworker.'

'Teleworker more relaxed - slightly more organised.'

Figure 10 shows how often colleagues contacted the teleworker at home. Only 25 per cent (4) felt more reluctant to contact them at home than in the office (of these two did not contact the teleworker at home at all, and two made contact once a day). 40 per cent of colleagues (6) rearranged their work to accommodate their colleague's teleworking.

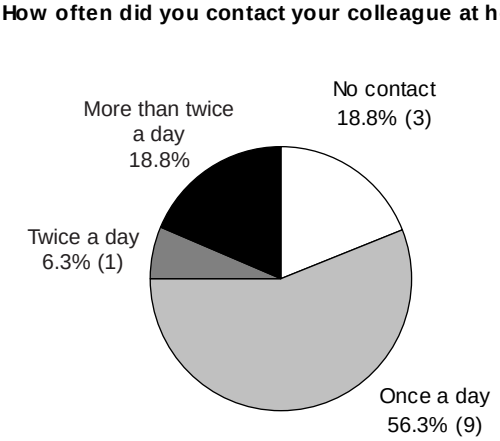


Figure 10 Level of contact during teleworking

Figure 11, Figure 12 and Figure 13 summarise the colleagues' opinion of the teleworking trial. The proportion of colleagues who felt their work had been affected was higher than anticipated by the teleworkers in the 'before' survey. Negative effects largely related to the colleague becoming a replacement point of contact to the teleworker for enquiries:

'I have felt that I have received more queries, questions and interruptions as a result of being around. Whilst he was contactable, people would rather come to me first. This affected my work negatively.'

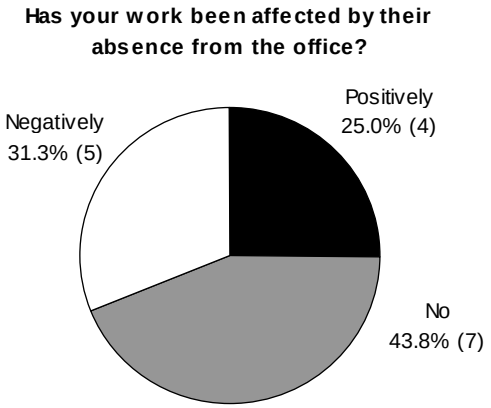


Figure 11 Effect on colleague's work

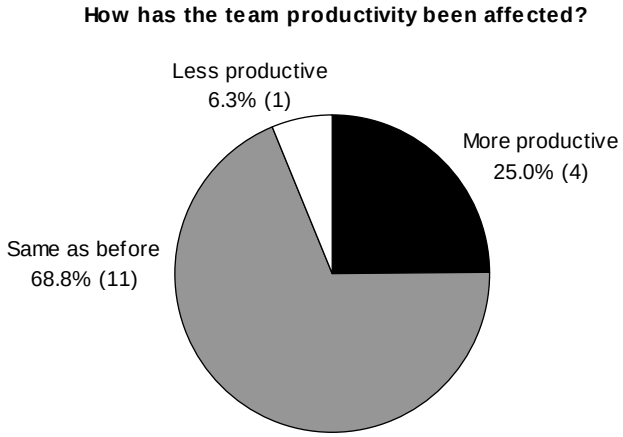


Figure 12 Team productivity

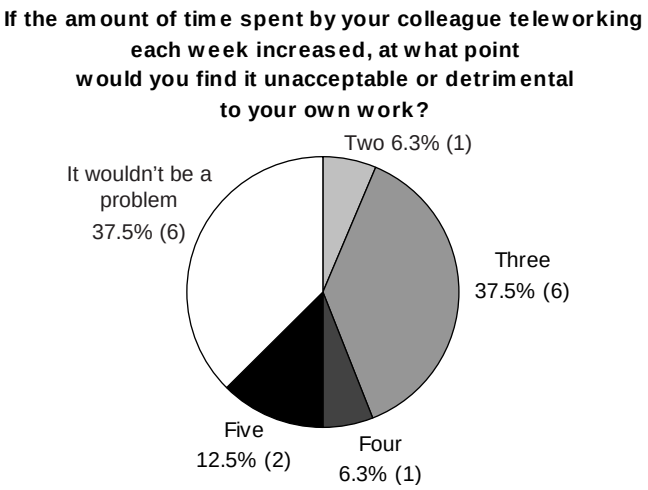


Figure 13 Unacceptable frequency of teleworking (in days)

Improvements in productivity indicated by the teleworkers themselves did not appear to be at the expense of the collective productivity of the team. Only one colleague said they would find a teleworking frequency of 2 days/week unacceptable. Just over half (9) of colleagues said they would find up to 3 days/week teleworking by their colleague acceptable.

3.6 Employers

Full responses were not obtained from the employer questionnaire. However this section outlines elements of the collected feedback that enhance or expand upon employer-related issues touched upon already. Employers' representatives were identified in each organisation. The nature of HCC was such that an employer's representative was identified for each Department associated with the trial. Information obtained from the teleworkers and colleagues has already offered a detailed account of how teleworking affected each organisation. Given that many of the teleworkers were in relatively senior positions it follows that their response information might also be deemed as representing the employer's perspective.

All responding employers' representatives had taken steps to investigate the insurance implications of teleworking and some had considered health and safety implications too. Support was of a technical nature where appropriate. No employers provided any personal support, which might reflect the maturity and capability of the individual teleworkers selected for the trial. Some equipment was purchased although some teleworkers were already sufficiently equipped for their needs away from the office. Start-up costs for the trial were, not surprisingly, variable. Gifford and Partners estimated that start-up costs were *'Very little for those involved who were all senior staff. Many already had compatible computers at home.'* The cost for one of the HCC teleworkers meanwhile was estimated at £5,000.

None of the respondents were able to say that their organisation had made any financial savings from teleworking except for some small savings in travel expenses. The short timescale of the trial is likely to have precluded a detailed estimation of financial savings.

Employers' attitudes towards teleworking remained positive at the end of the trial, although the extent of teleworking is likely to remain limited in each organisation. Full scale adoption of teleworking will require organisations to consider procedures, financial implications, contractual procedures and teleworker welfare. In this sense the trial did not represent a fully formalised working practice in each organisation. Teleworking would become more formalised in the longer term. Benefits of teleworking for the organisation were varied and are given as follows:

> *'Greater efficiency of work for those taking part. Reduced stress levels due to reduced travel.'*

> *'Reduction in travel times and costs. Improved response time to support calls. Improved motivation of staff.'*

> *'Potential reduction in office costs, improvements to recruitment where access (travel /parking etc.) costs are high e.g. Winchester; compensates for disbenefits of open plan accommodation on productivity.'*

'Flexibility for employer and employee. Builds trust between employer and employee. Contribution to environmental benefits. Increases use and understanding of technology.'

Disbenefits given by employers were equally varied:

'Provided only those who can telework effectively and efficiently are allowed to do so there are no significant disbenefits.'

'Managing a dispersed team - will have to be more formal'

'More open to abuse (i.e. staff not working hours). Telecommunications costs high. System infrastructure costs to fully support high (e.g. full electronic filing). For staff, loss of social aspects and team identity which would reduce effectiveness.'

'Difficulties with communication. Isolation of teleworker. Potential abuse of situation by teleworker. Potential for discontent on part of employees not involved with teleworking.'

Many of these benefits and disbenefits concur with the feedback provided by the teleworkers themselves. Perhaps most notable is the mention of trust, which tends to conflict with the impression given elsewhere that individuals are assessed by their output and indeed if anything fear themselves working longer hours.

Employers were also asked to comment on how they expected the incidence of teleworking to increase. One respondent estimated that more than 20 per cent of employees would be part-time teleworkers in five year's time. The remainder considered the figure to be between 5 and 10 per cent.

4 Evaluation

4.1 Energy and Emissions

4.1.1 Introduction

The combustion of hydrocarbon fuels leads to the production of carbon dioxide (CO_2), unburnt hydrocarbons (HC), carbon monoxide (CO) and particulates (PM) containing carbon and other contaminants. Sulphur dioxide (SO_2) is produced as a result of sulphur compounds present as impurities in the fuel. Also, at the high temperatures and pressures found in the combustion engine, nitrogen and oxygen in the air combine to produce nitric oxide (NO) and a small amount of nitrogen dioxide (NO_2), collectively known as NO_x.

Within ENTRANCE the evaluation of the applications was concerned with emissions of CO_2, HC, CO, PM, sulphur, NO_x and fuel consumption. Using known relationships between vehicle speed and emission rates, changes were calculated using information on journeys collected in the 'before' and 'after' surveys.

4.1.2 Impacts on domestic fuel consumption

It was expected that there would be some increase in fuel consumption within the home on teleworking days. A consequence of this additional domestic fuel consumption is increases in emissions from electricity production at power stations and gas/coal/oil combustion depending on the heating arrangements.

Many factors affect the amount of fuel required to heat the teleworker's working space. For instance outside temperature, the type of house and its degree of insulation, type of fuel, type of system, its age and condition, and heating arrangements during the day all have an impact. Because of the many variables very little information is available on average fuel consumption, and in particular disaggregated values for heating one room. Although this study did collect information on the participants' heating arrangements (see Section 2.2.3.4), it was considered inappropriate to estimate domestic fuel consumption given such a short period of study, as any increase calculated would be heavily skewed towards the higher usage occurring during late winter and early spring. This meant that the disbenefits of providing more heating and lighting at home would be overestimated.

4.1.3 Effect of teleworking on vehicle emissions and fuel consumption

4.1.3.1 Impact on travel habits

In terms of fuel consumption and pollutant emissions, the journeys normally made by private car, pool car and taxi offer potential for savings. It is reasonable to assume that for participants using public transport the vehicle would continue to do the same or a similar journey without them. No fuel consumption or pollutant emissions savings were calculated for journeys by public transport.

Table 15 showed that while a number of travel modes were used by the participants of the study, including walking, train and bus, the majority of journeys and distance travelled (some 80-90%) were made in their own car whether teleworking or not. During days when participants teleworked, the average number of journeys and their mean distance were reduced compared with days when they travelled to work. Before teleworking, participants in the trial travelled about 63 miles a day in their cars; on a teleworking day this was reduced to on average 21 miles.

Weekday travel habits of the participants where cars and taxis were used are compiled in Table 17. Journey characteristics before the teleworking and on non-teleworking 'after' days were remarkably similar in their number and duration (both in terms of distance and time). On teleworking days the number of journeys per day, and the average distance travelled in the participants' own car, was halved. This shows that a high proportion of the teleworking periods were full working days without commuting (and no journeys were made by pool car or taxi). The difference in frequency of use of cars, pool cars and taxis between teleworking days and non-teleworking days in the 'after' phase was statistically significant at the 95% confidence level.

Table 17 Weekday travel habits of the trial participants

	Average journeys per day	*Average journey distance (miles)*	*Average journey speed (mph)*
'Before'			
Own car	3.11	20.18	34.45
Pool car	0.04	40.65	34.45
Taxi	0.03	11.0	25.25
'After' non-teleworking days			
Own car	3.00	19.53	32.82
Pool car	0.03	28.60	24.90
Taxi	0	0	
'After' teleworking days			
Own car	1.38	14.91	26.74
Pool car	0	0	
Taxi	0	0	

4.1.3.2 Impact on fuel consumption and emissions

Both hot and cold start emissions will have been affected by the reduced number of journeys per day and distance travelled. The cold start period (i.e. while the engine is warming up) is particularly important as for this part of the journey, emissions are significantly higher than when the engine is hot. Using the values in Table 17 pollutant emissions and fuel consumption were calculated for teleworking and non-teleworking days during the trial. It has already been shown that there was very little difference between travel patterns before the trial and during the trial when the participants were travelling to work as normal.

The participants' vehicles were assumed to be passenger cars with a fleet composition (according to engine size, fuel and emissions control) similar to the national fleet. A combined emission factor for the affected vehicles was derived according to this distribution, as described in Appendix A. It is acknowledged that for the trial sample, with an above average income, the type of cars used may not correspond with the national average. However to ensure the results were comparable with those of the other ENTRANCE applications, it was felt emission factors derived for the national fleet would be the most appropriate, given the lack of alternative data on vehicle ownership.

It should be noted that cold start emission factors for PM from petrol vehicles were not available and so values for this pollutant are likely to be underestimates. All journeys were assumed to involve a cold start penalty.

Table 18 shows how emissions and fuel consumption were affected on days when the participants teleworked. Emissions and fuel consumption during teleworking were reduced to about 45% of those on a normal working day.

For both the trial and established teleworkers, Section 3.2 showed that the average frequency of teleworking was between 1.2 and 1.7 days per week. Assuming that the commuting journey was avoided on a teleworking day, the weekly savings due to teleworking were calculated. Table 19 indicates that an average week (Monday to Friday) might lead to savings of between 11% and 21% of fuel and pollutant emissions.

4.1.4 Conclusions

This trial has shown that the number of journeys and their average distance can be reduced if employees are able to telework. A reduction in journeys not only leads to less hot emissions due to the reduction in the distance travelled, but also the number of cold starts. Emissions during the period that an engine is cold are significantly higher than when the engine is hot, particularly for cars fitted with catalytic converters. This leads to significant savings in vehicle pollutant emissions and fuel consumption if teleworkers regularly work from home between one and two days per week.

It is acknowledged that the main disbenefit will have been the increase in domestic fuel consumption and associated pollutant emissions. However as the trial was for a relatively short period, and because of the lack of information on average fuel usage for heating and lighting, no estimates were made.

Table 18 Vehicle energy consumption and pollutant emissions for participants on weekdays during the teleworking trial

	HC (kg/day)	*CO_2 (kg/day)*	*CO (kg/day)*	*PM (g/day)*	*NO_x (kg/day)*	*Fuel (kg/day)*	*Sulphur (kg/day)*
Non teleworking day	0.07	10.8	0.31	2.86	0.10	3.62	0.07
Teleworking day	0.03	4.98	0.16	1.16	0.03	1.67	0.03

Table 19 Potential weekly savings in vehicle energy use and pollutant emissions for teleworkers

	HC (kg/week)	*CO_2 (kg/week)*	*CO (kg/week)*	*PM (g/week)*	*NO_x (kg/week)*	*Fuel (kg/week)*	*Sulphur (kg/week)*
Trial teleworkers	0.27	44.1	1.31	11.4	0.39	14.8	0.30
Established teleworkers	0.29	47.0	1.39	12.2	0.42	15.8	0.32
% Savings per week	13 - 19	12 - 17	11 - 16	14 - 19	15 - 21	12 - 17	12 - 17

4.2 Economic evaluation

4.2.1 Introduction

The evaluation of the teleworking application has highlighted a number of potential economic benefits. Most significantly teleworkers reduced their car use with a reduction in journey frequency and distance, resulting in a lower daily mileage. In this case benefits arose from time savings, reduced vehicle operating costs and lower fuel consumption. Even for those who teleworked part days there were potential benefits from reduced journey times and lower fuel consumption, where journeys were designed to avoid the main periods of congestion.

The purpose of the economic evaluation was to determine the potential benefits of teleworking to the economy as a whole. These benefits primarily came from reductions in the number of journeys. The evaluation did not attempt to determine the likely benefits to employers associated with increased productivity from their employees' teleworking.

The potential disbenefits of teleworking included the extra costs associated with providing equipment for use at home and fuel for heating and lighting rooms at home, which otherwise would have remained unheated and unlit. In common with the energy and emissions evaluation, the evaluation of domestic fuel use was not included in this analysis.

In the analysis all values of time and vehicle operating cost relationships were based on those from the COBA manual (Department of Transport, 1994). This is a user guide for the computer cost-benefit analysis program (COBA) and gives requirements for the economic assessment of road schemes. The analysis assumed 1996 prices net of taxes.

4.2.2 Change in car travel with teleworking

In common with the evaluation of energy and emissions, the analysis concentrated on the change in use of teleworkers' own cars, company pool cars and taxis. The figures in Table 20 are based on those taken from Table 17 in the energy and emissions evaluation. The savings shown in Table 20 are based on the figures in Section 3.2, which showed that the participants in the trial teleworked on 1.2 days/week whilst established teleworkers did so for 1.7 days/week. From this the total distance and time saved per person per year was calculated.

Table 20 shows significant savings in annual mileage and time in both the trial and established groups. For the trial teleworkers the annual savings for each person were estimated to be 3197 miles and 68 hours. For the more established teleworkers, the figures were higher, at 4173 miles and 94 hours.

4.2.3 Total savings from teleworking

Using the data in Table 20, Table 18 and Table 19 from the energy and emissions evaluation, annual savings in vehicle operating costs (VOC), time and fuel for both the trial and established teleworkers were calculated and shown in Table 21. These figures, when multiplied by the number of participants (24), formed the basis for the cost-benefit analysis (see Appendix B).

Table 21 Time, fuel and vehicle operating cost savings from teleworking

	Total VOC (£/year/ person)	*Total time (£/year/ person)*	*Total fuel (£/year/ person)*	*Total (£/year/ person)*
Before teleworking	893	1865	-	-
During the trial	700	1569	-	-
Savings	193	296	159	648
Established teleworkers	642	1448	-	-
Savings	251	417	170	838

1 It was assumed that there are 225 working days per year.

2 Price of fuel is 17.9 pence per litre (1996 prices net of taxes).

3 Density of fuel = 750g/litre.

4 Value of teleworkers' travelling time = £4.40 (1996 prices)(COBA, 1994).

5 VOCs were calculated using the formula C = a + b/V. Where C = cost in pence per kilometre per vehicle, a = 3.59, b = 13.08 and V average vehicle speed taken from Table 17. VOC values from COBA, 1994.

Table 20 Change in car travel on weekdays 'before' and 'after' teleworking

	Number of Journeys/ day/ person	*Distance/ day/ person (miles)*	*Time/ day/ person (hours)*	*Distance/ year/ person (miles)*	*Time/ year/ person (hours)*
Before teleworking	3.18	64.78	1.88	14575	423
During the trial	2.66	50.57	1.58	11378	355
Savings	0.52	14.21	0.3	3197	68
Established teleworkers	2.47	46.23	1.46	10402	329.1
Savings	0.71	18.55	0.42	4173	94

1 The before figures were assumed to be the same as the after non-teleworking days.

2 Teleworking in the main trial accounted for 1.2 days a week on average.

3 Established teleworkers spent on average 1.7 days per week at home.

4 It was assumed that there are 225 working days per year

4.2.4 Total costs of teleworking

Four employers participated in the scheme. By the nature of their business' they provided their employees with a varying amount of equipment. In the survey 18 out of the 24 participants responded to the questions about the equipment they used for the trial. Table 22 shows the types of equipment provided, their average cost and the number of people using each type of equipment.

Table 22 Teleworking equipment costs

Equipment type	*Average cost (£)*	*No. of users*	*Total cost (£)*
Telephone/fax	122	18	2196
Computer	1575	14	22050
E-mail link	105	7	735
ISDN link	2000	3	6000
Mobile phone	200	2	400
			31,381

The average cost of equipment used by each individual answering questions on equipment was £1743. The type of equipment used by the teleworkers ranged from just a telephone/fax (average cost £122) to the use of telephone/fax, computer, e-mail link and ISDN link (average cost £3802). Within each organisation different individuals would have had access to different types of equipment. It was found that everyone had access to a telephone, most people at the BBC and HCC had access to computers and e-mail links and some had ISDN links. Only the AA provided some of their employees with mobile phones.

4.2.5 Cost-benefit analysis

The cost-benefit analysis was undertaken for the main trial and for the established teleworkers. In the absence of equipment details and costs for the established group, figures for the main trial were used. Two time periods were selected for the analysis: over three and five years. These are periods of time over which equipment would usually be replaced. It was assumed that in both cases there would be an annual maintenance cost of 5% of total equipment value. The cost-benefit analysis used total annual costs and benefits for the whole group of 24 people. Total equipment costs were assumed to be the average equipment cost multiplied by 24.

The analysis showed that for the main trial, the costs would exceed the benefits over a three year period (i.e. if the equipment were replaced at the end of 3 years), although it would be economically viable over a five year period. Assuming a five year period, the Economic Internal Rate of Return (EIRR) was calculated to be 36%. This is the average return on investment, and represents the discount rate which, if applied, would give a Net Present Value of zero.

The findings for the established teleworkers provided a stronger case for teleworking; in this example, teleworking could also be regarded as viable over both a three and a five year period. It must be noted, however, that in general equipment costs are likely to be higher than estimated in the retrospective study, given the IT-based nature of the teleworkers' jobs. This may offset the benefits as reported. In the three year case an EIRR of 42% was calculated and this increased to 74% in the five year case. The full cost-benefit analysis is included in Appendix B.

4.2.6 Discussion

If teleworking becomes more widespread there is potential for it to have an impact on congestion and journey times for non teleworking commuters. This could result in fuel and time savings for a very large number of other motorists. In this analysis it was assumed that there was no impact on other traffic and that future traffic growth would not affect the characteristics of journey making by the teleworkers.

This trial was too small to have any long term impacts on employers. However, in the future employers may decide to adopt a policy of 'hot desking' to reduce the requirements for office space. This would not only affect rents but also heating bills, and would represent additional benefits from teleworking. For example it would help maximise the use of existing equipment, thereby reducing the additional set-up costs for teleworkers.

In addition to the economic considerations the study has shown that there are also some social benefits associated with reduced commuter times and, as a result, the increased time that workers can spend with their families. Although it is very difficult to quantify these benefits, an example may be that stress levels would be reduced, which in turn may reduce the number of working days lost through illness.

The study also highlighted 'hidden' benefits; the teleworkers in this study were already highly motivated individuals, but through more flexible working conditions, it was felt that quality and productivity of work is likely to increase. Higher staff morale is likely to impact positively on staff retention.

4.2.7 Conclusions

The results of the ENTRANCE trial have shown that there are encouraging indicators for promoting a wider use of teleworking. The results have shown that there are no obvious detrimental impacts on the productivity of the teleworker or of their colleagues and there could be a strong economic case for teleworking, particularly if a sizeable proportion of the workforce of a company are involved. This opens up opportunities for maximising the efficiency of the scheme's operation (for example by using 'hot-desking' to make the best use of available equipment, thereby reducing the additional set-up costs). Further benefits could accrue, which have not been evaluated in this study, which are associated with reduced stress, improved health and staff morale. The evidence provided by the more established group also suggests that as people become more familiar with teleworking the economic case improves because of the greater time they spend at home.

However, in the analysis no account has been taken of the increased use of gas and electricity for domestic heating or any costs associated with changes to the general traffic (e.g.

trip generation) as a result of teleworking. Consequently further work with a larger sample of teleworkers would be needed before firm general conclusions could be drawn on the overall costs and benefits of teleworking.

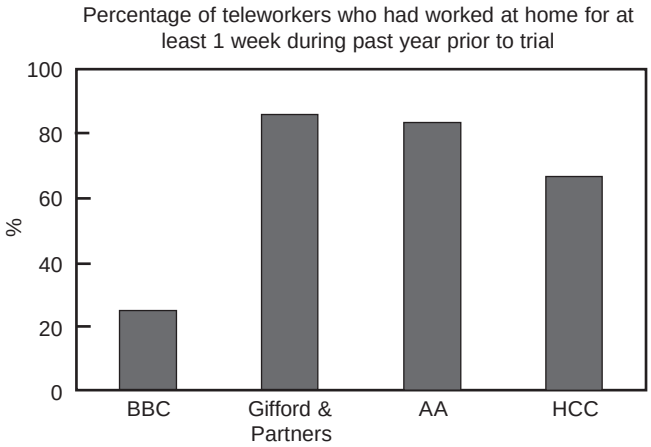
4.3 Behavioural evaluation

Many of the surveys' questions related to broad behavioural issues. Such questions attempted to perform two functions. Firstly to understand some of the social and institutional implications for teleworking and secondly to predict how such implications are likely to affect the extent to which teleworking is likely to be adopted in future. Adoption levels will ultimately govern the magnitude of the energy and environmental impacts of teleworking. Several behavioural issues have already been touched upon in Section 3. These are included in the summary (Section 4.3.7).

4.3.1 Understanding teleworking

A teleworker has been defined in this study as an employee who works at home or closer to home for part of their working week. In studies that consider the traffic and travel impacts of teleworking such a definition would typically stipulate a minimum frequency of teleworking days (Jarrett 1996, and Forsebäck 1995). This is intended to exclude from teleworking statistics individuals who practise, for example, only occasional isolated instances of home-working. At the 'Telecommute 93' conference in the United States the US telecommunications company Pacific Bell was praised for the high proportion of its own employees who were telecommuters. Closer inspection, however, showed that their statistics included people who worked at home one day a month (Gray, 1996).

In the 'before' survey, trial participants were asked about their recent experiences of working at home (Figure 1). Three fifths of the teleworkers in this trial had worked at home for at least a week during the year prior to joining the trial. Figure 14 presents the figures for each organisation. The majority of these are unlikely to have considered that, ignoring the matter of frequency, this constituted teleworking. Indeed, when asked whether the opportunity to telework had lived up to their expectations, one of the trial teleworkers responded:



Source: 'before' survey interview questionnaire

Figure 14 Home working prior to trial

> *'Yes - it's what I was expecting. I'd done something similar before, but it wasn't called teleworking.'*

The term teleworking is usually used to refer to people who work remotely on a regular basis (not necessarily working at home) who use computers and telecommunications to communicate with the employer's 'base' office. In this trial, all participants teleworked at home, and some did not use computers or specialised equipment, so for some, there was no difference between 'teleworking' and working at home.

4.3.2 Frequency

Over two thirds (70 per cent) of the trial teleworkers decided for themselves how often and when to telework each week. For the established teleworkers this figure was 85 per cent. The lower trial figure may be attributed to participation in a monitored trial. Some of the teleworkers from one organisation were either told how long to telework or came to a decision jointly with their employer. As Section 3.2 showed, the average frequency of teleworking for the trial teleworkers was 1.2 days per week compared with 1.7 days per week in the established group.

The relatively low frequency of teleworking meant that for some, at least, the effect on informal or social interaction with colleagues was not a problem, as Section 3.4 showed. Similar feedback was received from the established teleworkers - a minority felt isolated but again the issue of isolation was reconciled by the part-time nature of the teleworking:

> *'I don't think I'm at home enough to seriously affect this, although I'm sure that I'd be more of an 'outsider' if I worked from home more than two days per week.'*

When the trial teleworkers were asked how they would change their teleworking practice frequency was an issue for 22 per cent (13 per cent wanted an increase and 9 per cent wanted a decrease). A further 22 per cent of the teleworkers (principally representing those from Gifford & Partners) said they would seek a less formal arrangement, teleworking as and when appropriate:

> *'I would take a more varied pattern of teleworking. For example one day a fortnight or a day and a half in a week if it was needed.'*

During the trial some organisations and individuals had felt obliged to adopt a structured teleworking regime. At one organisation the employer was involved in deciding how much teleworking could be done by three people - and these three people resented being bound to this amount.

4.3.3 Benefits to employees of teleworking

Potential future teleworkers, if presented with the opportunity to telework, are likely to decide whether to do so on the grounds of the perceived benefits and disbenefits. Figure 15 groups teleworker responses concerning benefits

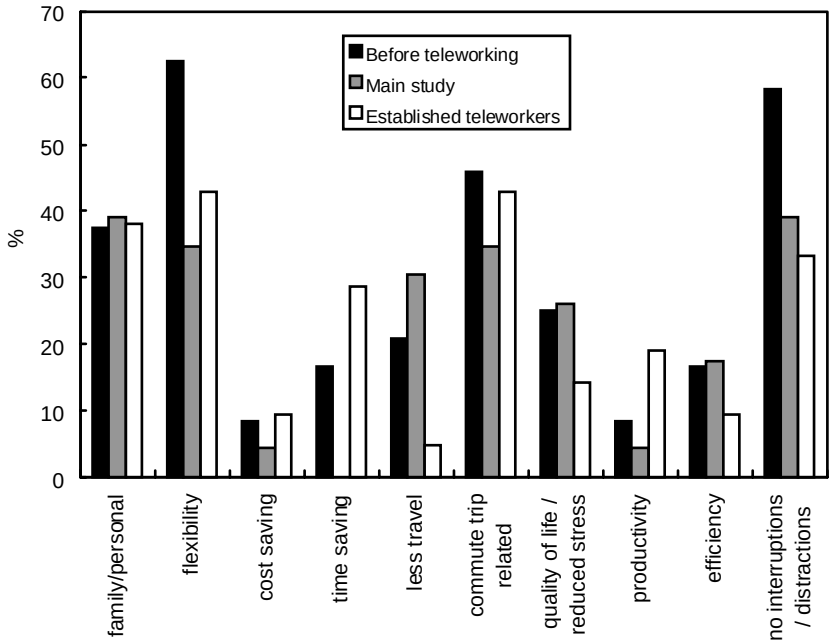


Figure 15 Benefits of teleworking

for the main trial and the retrospective survey of the established group. The commute journey related category is an aggregation of the following categories: cost saving, time saving and less travel.

An element of consistency existed between the before, after and retrospective studies. Four clearly identified benefits are:

- the opportunity to meet the requirements of family and personal life;
- the opportunity to work without interruption or distraction;
- increased flexibility; and
- commute journey related benefits.

These represented the most frequently cited benefits in all three surveys. However a comparison between the 'before' and 'after' surveys suggests that some expectations were not met, in terms of flexibility, cost saving, and time saving. Figure 15 should be viewed carefully. Despite the relatively small proportion of responses that explicitly identified productivity and efficiency as benefits, it may, in many instances be assumed that these benefits are implicit in terms of the lack of interruption and distraction leading to more productive and therefore more efficient time. Indeed, the teleworkers collectively identified improved productivity and efficiency as the highest ranking employer benefit (see below).

A number of interesting and pertinent comments were noted:

'being able to work when I feel creative, as opposed to within office hours.' (source: 'before' survey)

'Not having to drive in bad weather - though that hasn't happened yet.' (source: 'after' survey)

'I think my mileage has gone down, because if you're really stressed and everything's buzzing, you'll think 'I'll go and see so-and-so', but if I'm at home, I'll try and resolve it over the phone.' (source: 'after' survey)

'Lower stress levels, it's the nicest day of the week when I control my own destiny. I don't have the hassle of driving in to work.' (source: 'after' survey)

'Able to live far from the office.' (source: 'after' survey)

'I don't need to move house and disrupt my family.' (source: 'after' survey)

'I had a lot of miscarriages before I teleworked, and now, probably because there's not as much stress, and I feel more relaxed, I've managed to become pregnant.' (source: 'after' survey)

4.3.4 Disbenefits to employees of teleworking

Figure 16 highlights a number of disbenefits, although most of them did not appear to present widespread concern. Notably in the trial the number of teleworkers who saw no disbenefits from teleworking doubled once they had gained first-hand experience of teleworking. For example a number of the expected disbenefits did not arise. These were: personal cost, reduced office presence, the issue of home-work distinction, perceived availability outside office hours, and working longer hours. This suggests that several disbenefits that may be used to justify avoidance of teleworking are derived from a lack of familiarity with the working practice. However there was a slight increase in disbenefits associated with 'inaccessible office facilities, staff and information' between the

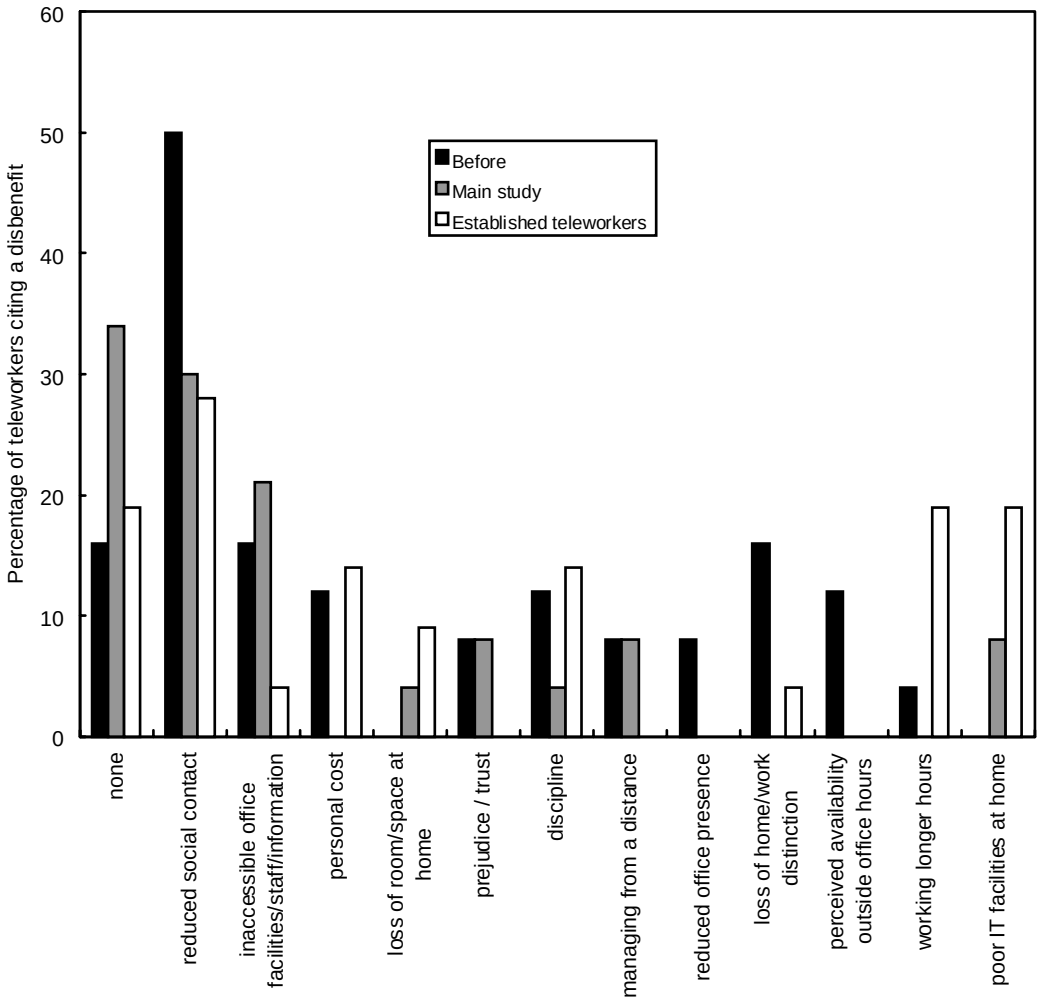


Figure 16 Disbenefits of teleworking

'before' and the 'after' surveys. Several comments are again worth noting:

> *'It's difficult explaining to an eight-year-old that you are home but not available, because they feel cheated sometimes. It's not really a disbenefit, just something to be aware of.'* (source: 'after' survey)

> *'Very occasionally it would be useful to speak to other team members face-to-face, but there's only been that one occasion when we were out of synch. Otherwise I don't think there are any. I wouldn't want to do it full time, but one or two days a week is of great value.'* (source: 'after' survey)

> *'A small degree of prejudice. The discipline required for time management. The need to co-ordinate my teleworking with other teleworkers.'* (source: 'after' survey)

> *'The desk takes up room in the dining room (I wish I had chosen a house with an extra room). My wife expects to be able to interrupt me if I am at home.'* (source: retrospective survey)

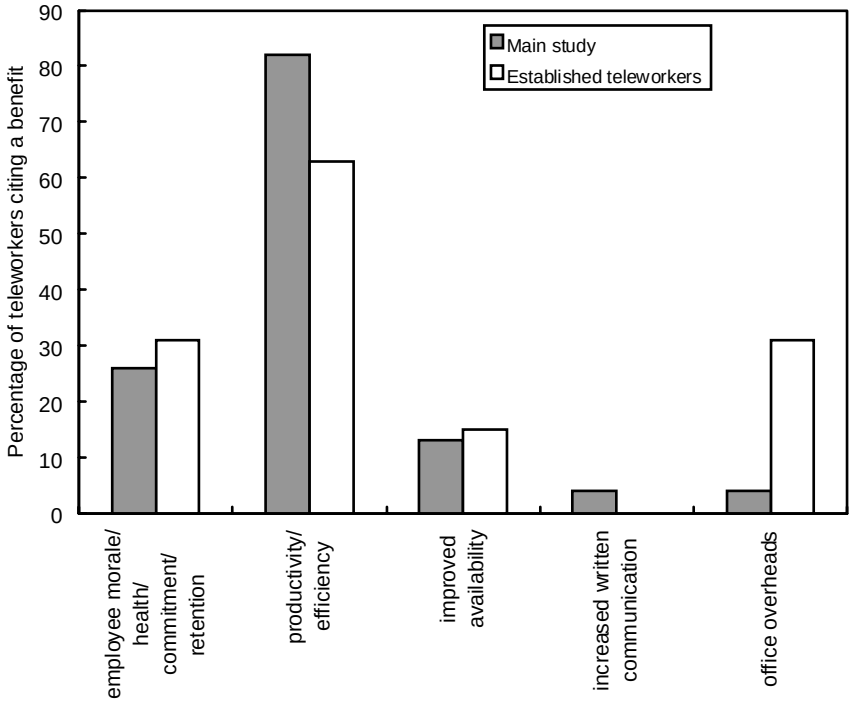
4.3.5 Benefits and disbenefits to employers

Figure 17 shows the employer benefits as perceived by the teleworkers. What cannot be noted from the responses is the magnitude of the benefits and disbenefits stated. However, it can be inferred that overall benefits outweigh disbenefits. All but one of the trial teleworkers indicated that they would, if permitted, continue to telework. Besides this one teleworker, expectations from the opportunity to telework were met and in several cases exceeded by those participating in the trial:

> *'I think it was better than I expected. Initially it was quite difficult, but in the end it's made me more efficient.'*

> *'I didn't really have too many initial expectations, but I've been surprised how well it's worked.'*

These two comments demonstrate an important point. Perceptions about a new working practice can be misplaced and adjusting to a new working practice takes time. All the established teleworkers in the study had their expectations met (perhaps not surprisingly, since they remain as teleworkers).



Source: Teleworker Interview Questionnaire

Figure 17 Benefits to employers

There was a clear belief among the employees that they were delivering more value for money to their employers and in many cases this was a consequence of 'feeling better'. This corresponded with expectations in the 'before' survey, where the most frequently cited benefit to employers was improved productivity. A third of established teleworkers mentioned the benefit of reduced office overheads, in contrast to only 4 per cent in the trial. This may have been due to the established nature of their teleworking, the fact that on average this group teleworked 2.3 days per week (above average for the sample as a whole) and that the computer-based nature of their work was more likely to lend itself to practices such as hot-desking.

Perceived disbenefits to employers according to the teleworkers are shown in Figure 18.

A clear message emerged from the trial: the concern related to managing from a distance. It should be stressed that this related to management in two directions: either the teleworking manager dealing with subordinates, or managers dealing with teleworking subordinates. It can be assumed that accessibility and face-to-face communications will relate to such distance management and serve to compound any management concerns. This concurs well with existing literature. One of the most important obstacles to adoption of teleworking in 1985 (according to a European Survey cited by Forsebäck (1995)) was the high IT cost. Nine years later this had dropped in importance to be replaced by the difficulty in managing from a distance and inadequate knowledge of what telework really is.

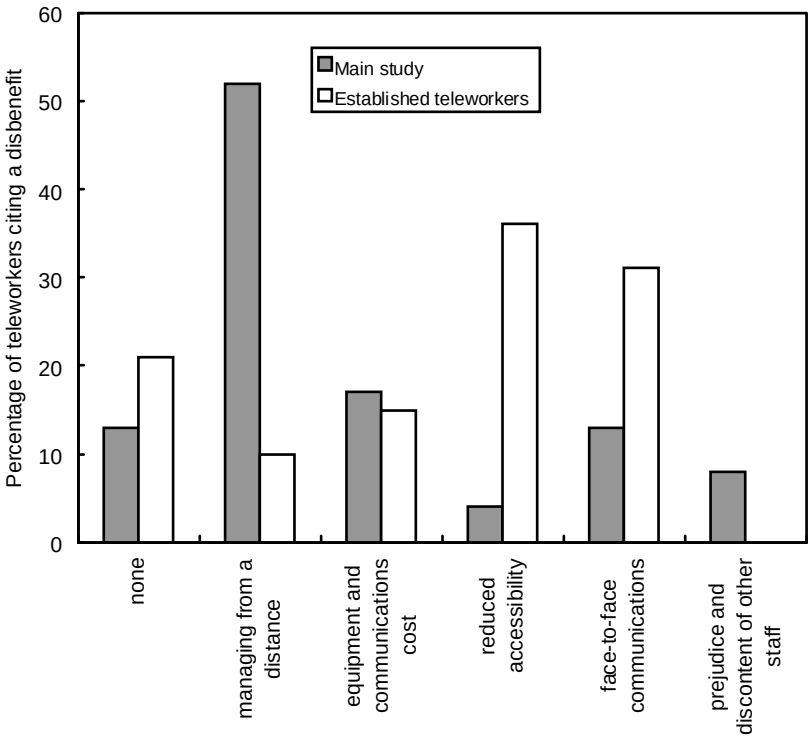
4.3.6 Technological requirements

Figure 19 shows what changes the trial and established teleworkers would have liked to make to their teleworking practice. Both sets of teleworkers collectively saw the need for improved telecommunications/computing facilities as the main improvement to their teleworking. It would appear from the above statement concerning high IT cost, that while IT costs may be falling, provision of IT for home working does not meet the growing requirements. It could also be inferred that the higher percentage of teleworkers not requiring any changes in the established group compared with the 'after' study is a consequence of the former having evolved their working practice over a longer time period.

4.3.7 Summary

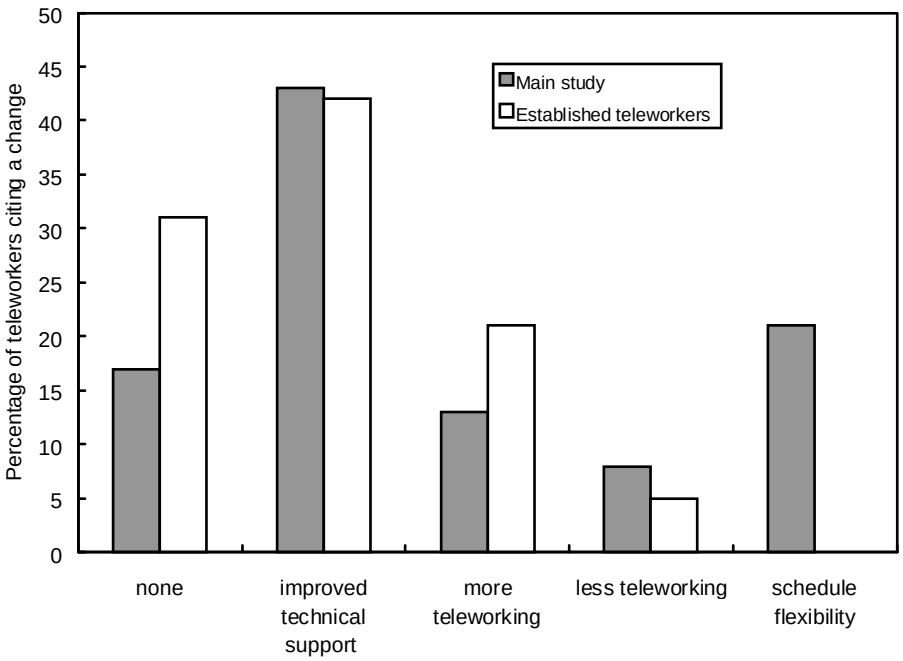
Behaviour will ultimately govern the extent of energy and environmental impacts of teleworking. Key factors include: the current and future adoption levels of teleworking; the frequency of teleworking (and consequently what proportion of the workforce will be teleworking on any given day); and the choice between part and full-day teleworking.

The extent to which teleworking is adopted will be governed by both employer and employee *awareness* and *understanding* of what teleworking is and the benefits (and disbenefits) of such a working practice. A majority (62 per cent) of the teleworkers in the trial had (informally) worked at home prior to the trial for at least a week over the previous year. All but one of the teleworkers wished to continue the formalised teleworking practice. Expectations (whether related to positive or negative aspects of teleworking) tended to be more extreme than the actual experience of teleworking. This, and various observations from the surveys, suggests that individuals need to have first hand experience with teleworking to fully understand its characteristics. Adapting to such a working practice also takes time:



Source: Teleworker Interview Questionnaire

Figure 18 Disbenefits to employers



Source: Teleworker Interview Questionnaire

Figure 19 Preferred changes to teleworking practice

'I find it much more useful than I thought it was going to be. At first it was very difficult but once I'd got into the routine it worked much better all round.'

'During the time that we took part in the experiment, attitudes generally towards teleworking became increasingly positive, and we thought about ways to improve productivity further by working along those lines in the future.'

An established teleworker commented that:

'I don't think teleworking will suit all persons or all jobs. However, I think more people should be encouraged to at least try it. I'm sure most of us go to work out of habit rather than need.'

It may be that human resistance to change will continue to inhibit teleworking uptake so it is important that the process of informing and educating businesses and individuals should continue.

Increased flexibility, the opportunity to better manage personal and business commitments, working in a less distracting environment and removal of the stress and/or cost of the commute journey are seen as the principal benefits for teleworkers. These personal benefits translate into improved productivity and staff morale for employers.

The teleworkers in the trial were highly motivated individuals predominantly in management positions. They were clearly identified by their employers as responsible and disciplined individuals who were able to work unattended. It might be speculatively inferred that such attributes are necessary for teleworking to be a success. This would mean that only a limited proportion of the total workforce would make suitable teleworkers. Further to this, many job types will remain inappropriate for teleworking, irrespective of the characteristics of the individual. This suggests that while adoption levels could be improved, penetration of the workforce will remain limited.

The frequency of teleworking, or more specifically home working, appears set to remain between 1 and 2 days per week on average. At this level teleworking delivers a net benefit to employees and employers. If the frequency is increased then concerns about interaction with colleagues and managing from a distance become more pertinent issues.

The principal benefit accrued on a teleworking day is the removal of the commute journey. Of the trial teleworkers, 70 per cent had *sometimes* teleworked part days. In some cases no commute journey was made but work was conducted out of the office (and away from home), in others a commute journey was still made. If the latter was to occur on a regular basis then the energy and environment related benefits of teleworking would be seriously compromised. However, indications suggest that such part day teleworking was not desired by the teleworkers. It must be hoped that over a longer period of time established teleworkers would be able to successfully re-schedule activities to ensure full-day teleworking.

In conclusion, the behavioural evaluation suggests that there is further potential from teleworking yet to be realised, through greater understanding of what teleworking is and what it can offer, which may best be gained by practical experience of this form of working. Teleworking will not be a stand-alone panacea for problems of energy consumption, congestion and pollution. Adoption levels will be limited and the low frequency of teleworking days will further restrict the percentage of the total workforce that are teleworking on a given day. However teleworking can provide a significant contribution to mitigating transport-related problems and the social difficulties associated with modern lifestyles.

5 Discussion

In addition to providing information on the energy, emissions, behaviour and economic aspects of teleworking, the process of setting up a trial has highlighted the more basic methodological issues and difficulties involved. The initial target sample size for the trial was 100 teleworkers selected from four or five employers. Initially, 25 organisations were contacted and 11 follow-up face-to-face meetings were arranged. Further to this a telemarketing company was enlisted to approach approximately 150 smaller organisations.

Despite this extensive 'recruitment' exercise, only four organisations joined the trial. Some of the major organisations that declined to join the trial can be placed in three groups:

- Those who expressed an interest in teleworking but decided that their organisation was not suitable for teleworking (14).
- Those who believed that teleworking would play a role in their organisation in the future but did not see it as appropriate at that time (11).
- Those that were already involved with teleworking and did not see that the ENTRANCE trial would provide added value (5).

There was also a general difficulty in identifying an individual in an organisation who had the authority to modify policy on working practices.

The teleworkers, colleagues and employers in the trial were expected to provide a high level of feedback. This created a series of difficulties and instances of non-response at the various stages of the trial. Two teleworkers left their organisations during the trial. Fortunately both departures took place towards the end of the trial with minimal loss of feedback information. Monitoring during the 'after' stage was deliberately set to capture behaviour during weeks when teleworking was taking place. In one instance, an individual recorded a week of travel data despite not teleworking. Although time had originally been set aside in that week for teleworking, last minute commitments removed the opportunity to telework.

However despite the smaller than ideal sample size this was is balanced by one of the most detailed monitoring programmes of such an activity. Its importance is further established through the relative absence of similar studies

in Europe compared with the US. The findings from this study broadly concur with results from the other studies.

In a review of survey methodologies of teleworking trials, Mokhtarian et al (1995) reviewed eight studies (representing a total sample of 382 teleworkers) which were considered to be the best efforts to date at analysing the travel and travel-related impacts of teleworking (see Table 23). The authors illustrate the complexity associated with obtaining good data for analysis from such trials by outlining an ideal evaluation method:

> *'The ideal evaluation method would include travel diary surveys before and after the start of the telecommuting program. Travel diary surveys collect data on non-work travel as well as the commute journey, and provide data on travel mode, destination (and thus distance), time of day, and travel time. For the evaluation of telecommuting such a survey should cover telecommuting and non-telecommuting (i.e. regular commuting) days. A full 7-day diary would permit an analysis of the shifting of journeys not only between telecommuting and non-telecommuting days but also between weekdays and weekends.*
>
> *Surveys before and after the start of the program allow for an evaluation of changes that have occurred. Multiple after-surveys would allow for an evaluation of how these changes evolve over time: do the initial impacts taper off as the novelty wears off or do the impacts increase as people become accustomed to telecommuting?*
>
> *The household member survey will reveal changes in journey responsibilities among household members that might occur as a result of telecommuting. Finally a control group of non-telecommuting employees (and their household members) should be surveyed as well. The control group's behaviour will reflect background changes affecting everyone, and thus will provide a base against which the travel characteristics of the telecommuters can be compared. For example a sizeable increase in gasoline prices, or a nationwide recession, could be competing explanations for an observed reduction in discretionary travel after telecommuting begins. Having a control group permits the effects of such broadly applicable factors to be isolated from the effects specific to telecommuting.'*

In practice the extent to which different trials conform to such an ideal is variable. Indeed certain aspects of this ideal might be deemed impracticable. For example the use of a control group has been argued against (Hamer et al, 1991) on the grounds that such a group would probably react very differently to a survey task of filling in journey diaries, with little incentive (in contrast to the teleworkers themselves) to complete the task satisfactorily.

Table 23 Sample sizes and methodologies for ENTRANCE and previous studies (adapted from Mokhtarian et al, 1995)

Study	*Sample size*	*Before?*	*After?*	*Travel diaries?*
ENTRANCE	24	✓	✓	7 days
State of California	73	✓	✓	3 days
Puget Sound	63	✓	✓	2 days
Netherlands	30	✓	✓	7 days
SCAG	18		✓	partial day
San Diego	34		✓	partial day
Arizona/AT&T	99		✓	
Bell Atlantic	50		✓	
REB	15		✓	

In conclusion the difficulties of establishing and conducting a teleworking trial cannot be underestimated. The nature of jobs being performed is unique to each organisation and in many cases to each individual. Likewise, domestic arrangements and travel behaviour vary considerably. Such variation precludes a straightforward methodology for and management of a monitoring process. A high level of supervision is required to ensure a satisfactory body of data is assembled for evaluation.

6 Summary and recommendations

6.1 Summary

Teleworking has been the subject of an increasing number of studies. However, studies for which transport related issues are the focus remain limited and as such the ENTRANCE teleworking trial represents a valuable contribution. This is particularly so as it is one of the few studies conducted outside the United States. The trial involved a detailed methodological approach and yielded both qualitative and quantitative databases. Many of the findings corroborate those from other studies.

A trade-off was made in the study between sample size and survey requirements and detail. Although studies with larger samples have been conducted elsewhere, the ENTRANCE trial acquired a level of detail that enabled a number of specific impacts and issues associated with teleworking to be identified. The unique use of a combined study of established teleworkers provided added value to the study in a number of areas and was useful in demonstrating that many impacts observed during a short-term trial were likely to persist in the longer term.

In common with other ENTRANCE applications, four categories of impacts were considered, namely energy, environmental, economic and behavioural impacts. A summary of the main impacts can be seen in Table 24. The energy and environmental impacts were closely related to the impacts on journey making. Changes in journey making also contributed to the economic impacts as did changes in behaviour. Monitoring and evaluation of the teleworking trial paid particular attention to behavioural issues since these ultimately govern the proportion of people who will become teleworkers and the extent to

Table 24 Summary of quantifiable impacts on weekdays

	Before the teleworking trial	*On tele-working days*	*% Decrease*
Journeys per day	3.6	1.38	67
commute	1.5	0.2	86
work-related	0.8	0.2	75
other purpose	1.4	0.8	43
by own car	3.11	1.48	52
Distance travelled (miles) per day	74.5	15.9	79
commute	32.0	4.8	85
work-related	14.8	3.5	76
other purpose	27.7	7.6	73
by own car	63	21	67
Fuel consumption (kg per week per person)*	18.1	15.0–15.9	12–17
Emissions (per week per person)*			
HC (g)	337	275–293	14–20
CO_2 (kg)	54.0	44.7–47.5	12–17
CO (kg)	1.58	1.33–1.40	11–16
PM (g)	14.3	11.5–12.3	14–19
NO_x (g)	502	394–426	15–21
Sulphur (g)	362	300–318	12–17
Costs ((£/year/person)*			
Vehicle operating costs	893	642–700	22–28
Time costs	1865	1448–1569	16–28

** Assumes 1.2 - 1.7 teleworking days per week.*

which teleworking is practised. The percentage of the nation's total workforce that is teleworking on a given day ultimately dictates the magnitude of any energy, environmental and economic impacts.

The results of the trial remain, to some extent, a reflection of behaviour and opinion associated with a small sample of individuals whose characteristics might be classed as atypical of the population at large with above average incomes, commute distances and household car ownership levels. Nonetheless such characteristics are arguably representative of teleworkers, particularly those who became teleworkers at a relatively early stage in the development of teleworking.

The principal travel related benefit of teleworking was that morning and evening commute journeys were not made. The travel diaries confirmed that on most teleworking days this was the case and that a substantial reduction in work-related journeys also occurred. It might be assumed that teleworking is always a full-day activity. However it was found that on occasions many of the participants teleworked for part-days in conjunction with travelling into the office to work or making work-related journeys from home. A journey into the office no longer results in the removal of the commute journey. However, the potential offset of benefit that this practice causes was not considered to be substantial. Firstly, part-day teleworking still results in removal of one or both of the commute journeys from the peak periods and, secondly, this was not a regular practice but one which, on occasion, became unavoidable because of work commitments.

The use of vehicle logs in conjunction with travel diaries revealed that no significant use was made of the teleworkers' travel-to-work vehicles on teleworking days by other household members and indeed no increase in personal journeys made by the teleworkers was seen on teleworking days. Both these practices, had they occurred, would have served to offset the benefit derived from the removal of the commute journey.

The frequency of teleworking averaged 1.2 days/week although for the established teleworkers this was somewhat higher at 1.7 days/week, with a higher rate (2.1 days) for those who had been teleworking for 4 years. The higher rate for the established group may have been a result of teleworking becoming an established working practice, although it may be explained in part by the more IT-related nature of the work being undertaken and the potential reduction in need for face-to-face contact. However, in the context of teleworking as defined in this study, teleworking appeared set to remain a part-time activity practised typically for one or two days per week. Similar frequencies have been observed in other studies. This limits the aggregate impacts of teleworking on any given day, assuming an even spread of teleworking through the working week.

A potentially significant longer term impact of teleworking is its permissive role in a home or job relocation, leading to longer commute distances compensated by fewer commute journeys per week. Such resulting increases in commute distances were found in two cases in the established group. It might therefore be argued that teleworking promotes suburbanisation or urban sprawl. However, while longer commute journeys may result, thereby increasing vehicles miles travelled as a result of relocation, fewer journeys (in the peak period) will still be taking place. Thus benefits for peak period congestion and vehicle emissions can still be accrued.

Teleworking was seen by those involved as an attractive working practice allowing more flexibility, the opportunity to meet the requirements of family and personal life, and the opportunity to work without interruption or distraction. For some at least, it was in practice indistinguishable from 'working at home'. The principal disbenefit for employers was perceived to be managing from a distance. However clear benefits were also seen with improved staff morale, reduced stress and improved employee productivity/ efficiency. It was notable that in the 'before' stage of the trial 15 per cent of participants perceived there to be no disbenefits for themselves from teleworking. In the 'after' stage this figure doubled to over 30 per cent. A number of the anticipated disbenefits did not arise. Although some of the expectations were not met, upon completion of the trial all but one of the participants expressed a wish to continue teleworking if given the opportunity to do so. This provides a strong indication that education and awareness have an important role to play in promoting and encouraging the uptake of teleworking.

The recruitment process to secure participants for the trial provided some measure of the potential extent of teleworking adoption in the Southampton region. Over 150 organisations were approached of which only four major

employers chose to participate. For the 41 major employers approached, reasons for non-participation were obtained. Three distinct groups of non-participating organisations existed: those who expressed an interest in teleworking but decided that their organisation was not suitable for teleworking (14); those who believed that teleworking would play a role in their organisation in the future but did not see it as currently appropriate (11); and those that were already involved with teleworking at various stages of implementation/evaluation (5). The five organisations in the last group are an encouraging sign for adoption levels amongst major employers. Nonetheless these recruitment findings alone suggest that uptake of teleworking is likely to be evolutionary rather than revolutionary and concur with the observations of others (Korte et al, 1994). However it is unlikely that more than a proportion of the workforce will be able to telework in the future. The teleworkers in this study were predominantly managers who were self-disciplined and highly motivated and who required uninterrupted time away from the office. Many individuals and indeed job descriptions will never be suited to teleworking. Handy and Mokhtarian (1996) assume that the maximum penetration in the United States is 40 per cent.

Set against the nature and extent to which teleworking was practised in the trial, emissions and economic evaluations were carried out. Vehicle emissions are strongly related to the number of cold-starts and in turn to the number of journeys taking place. Based on a frequency of teleworking of one to two days per week it has been estimated that savings of between 12% and 22% of fuel and pollutant emissions can be made per week. The short timescale of the trial and the data collection demands on the participants precluded an assessment of changes in domestic energy consumption.

The economic evaluation was unable to encompass all of the contributory factors since they could not be determined from the short timescale of the project. However it was estimated that for the trial teleworkers, the costs of teleworking would have been outweighed by the benefits over a five-year period and for the established teleworkers this was reduced to three years. It has been demonstrated in this study that at the 'trial' stage an employer can keep expenditure to a minimum whilst the selected staff explore the kind of facilities and telecommunications that are required to enable them to telework efficiently.

Teleworking is not a panacea for congestion resulting from rising travel demands. It provides clear short term benefits particularly in reducing peak period travel demand. However the scale of such benefits is dictated by the percentage of the workforce teleworking on a given day. Although a number of key impacts have been noted in this study, ultimately quantitative measures of magnitude must be established to determine the aggregate effects on travel demand. This can only be achieved if regular large scale surveys are conducted to collect the necessary data. Nonetheless this study has provided a valuable insight into, and recorded, travel demand impacts of teleworking. The principal benefit of teleworking, namely the reduction in the number of commute journeys, does not appear to be substantially diminished by secondary impacts. Also the costs involved are largely borne by individual employers rather than the local authorities. Although in the long term some adverse effects may result, in the short term teleworking does provide a useful and economically viable travel demand management tool that can achieve reductions in fuel consumption and emissions. It is a tool that will be of growing value if the number of people practising teleworking can be increased.

6.2 Recommendations

This trial has demonstrated that teleworking part of a working week can contribute to policies to reduce fuel consumption and vehicle emissions. The main recommendations from this study are that:

i further research should concentrate on demonstrating the longer term impacts of teleworking on energy consumption and expenditure at home and at work. This was not feasible in this study due to time constraints;

ii education and awareness have an important role in encouraging the uptake of teleworking, and further trials would therefore benefit from publicising the benefits demonstrated here.

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Appendix A: Calculation of energy and emissions

A1 Background

This appendix sets out the approach to the evaluation of the energy and environmental impact of the teleworking application. The approach is common for all the applications in ENTRANCE, except those involving the alternative fuels buses where direct measurements of pollutant emissions and energy consumption are made. Within ENTRANCE the evaluation of the applications was concerned with emissions of carbon dioxide (CO_2), hydrocarbons (HC), carbon monoxide (CO), particulates (PM), sulphur (S), nitrogen oxides (NO_x) and fuel consumption. Using known relationships between speed and emission rates, changes were calculated using data on numbers of journeys and journey times (which were used to calculate speeds) collected in the surveys.

A2 Emission and fuel consumption factors

A2.1 Sources of data

In common with the other ENTRANCE applications, German data on emissions were used. For some applications it was important to have data on a comparable basis for emissions from buses and cars. Data on emissions from buses are available for Germany but not for the UK. Therefore the source of data for emissions used in all the applications, including teleworking, was the Workbook on Emission Factors for Road Transport in Germany and Switzerland (FEA, 1995), known as HB-EFA.

A2.2 Passenger car emissions

There is more conformity between Swiss/ German and UK passenger cars, and that combined with the common emission standards means that the HB-EFA data are quite similar to UK data, as Figure A1 shows.

Each passenger car type is required to conform to different emissions standards according to the relevant EC emissions control legislation (at the time when it was registered), size of engine and fuel type. To simplify the calculations a combined relationship between speed and emissions was required, to account for all the different types of vehicles on the roads.

In this study passenger cars were assumed to fall into ten

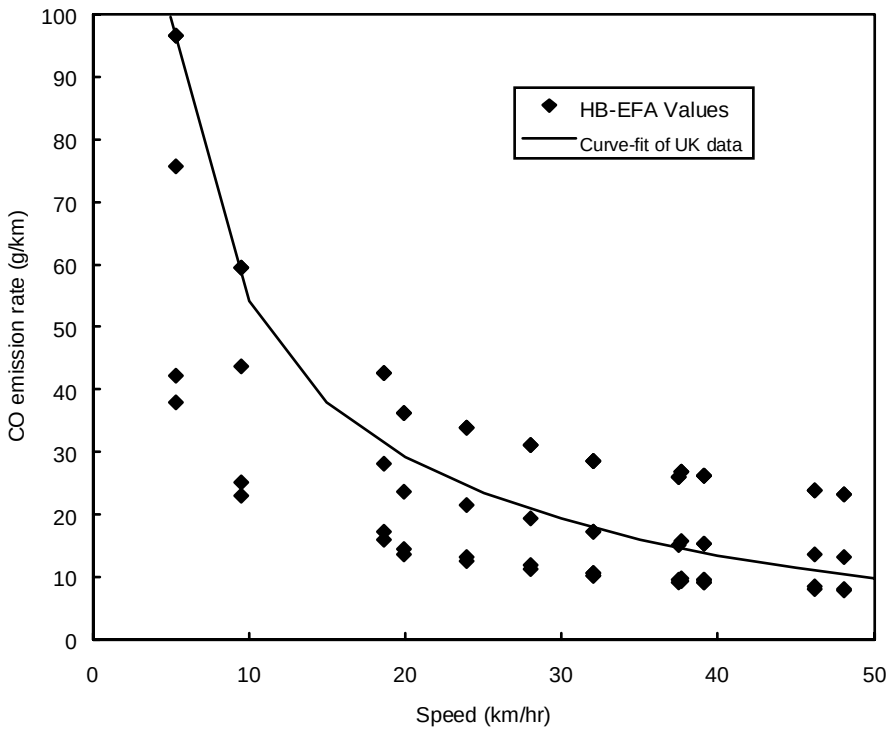

Figure A1 Comparison of CO emission factors for non-catalyst passenger cars

categories according to fuel type, engine size and EC emissions control legislation. It was also assumed that the vehicles affected were of a similar composition in terms of the proportion of vehicles in each category, to that of the national fleet. According to the number of vehicles and their annual mileage (Table A1), a weighted distribution of the proportion to which each vehicle category contributes to traffic emissions as a whole was calculated (Figure A2). This distribution was then used to calculate a combined speed-emission factor from the rates for the individual categories.

Table A1 UK vehicle car fleet composition (Hickman et al, 1997)

Passenger car category (fuel, EC emissions control category and engine capacity)	*Total number in each category*	*Total mileage in each category*
All diesel, >2 l	562805	47662.89
All diesel, <2 l	375203	40107.64
All petrol, 15.01/02	34734	12579.44
All petrol, 15.03	3493517	9918.50
All petrol, 15.04, < 1.4 l	5197438	15119.52
All petrol, 15.04, 1.4 - 2 l	5277574	15119.52
All petrol, 15.04, > 2 l	468741	13168.20
All petrol, 91/441, <1.4 l	3161603	20986.82
All petrol, 91/441, 1.4 - 2 l	3210350	20986.82
All petrol, 91/441, >2 l	1096278	19121.87
All categories	22878243	

A2.3 Calculation of speed-emission curves

HB-EFA allows the determination of speed-emission curves for CO, CO_2, HC, PM and NO_x from a knowledge of the type of vehicle. Using the distributions of types of passenger cars a combined speed-emission curve for each pollutant was derived according to the proportion of each vehicle type in the traffic stream.

Emissions from vehicles operating below their normal operational temperature are elevated. This is particularly so for cars with catalysts where there is a delay in reaching optimum efficiency. Such are 'cold starts' and emissions produced during this period were calculated as a penalty over and above hot emissions. Cold start emission factors were also calculated using the HB-EFA model and the passenger car distribution described above.

Fuel consumption was derived from a mass balance of carbon atoms in the exhaust. The mass emissions of CO, CO_2, HC and PM found using the factors derived above were in turn used in the following equation to calculate the mass of fuel consumed (Eggleston et al., 1993).

$$M_{FUEL} = (12.011 + 1.008 \times r_{H/C}) \times \left(\frac{M_{CO2}}{44.011} + \frac{M_{CO}}{18.011} + \frac{M_{HC}}{13.85} + \frac{M_{PM}}{12.011} \right)$$

where:

M denotes the mass of fuel, CO_2, CO, HC and PM;

$r_{H/C}$ is the ratio of hydrogen to carbon atoms in the fuel (1.8 for petrol, 2.0 for diesel).

Emissions of sulphur were estimated by assuming that all the sulphur in the fuel is emitted e.g.

$$M_S = k_s \times M_{FUEL}$$

where k_S is the sulphur content of the fuel. For petrol this is 200 ppm for diesel 500 ppm.

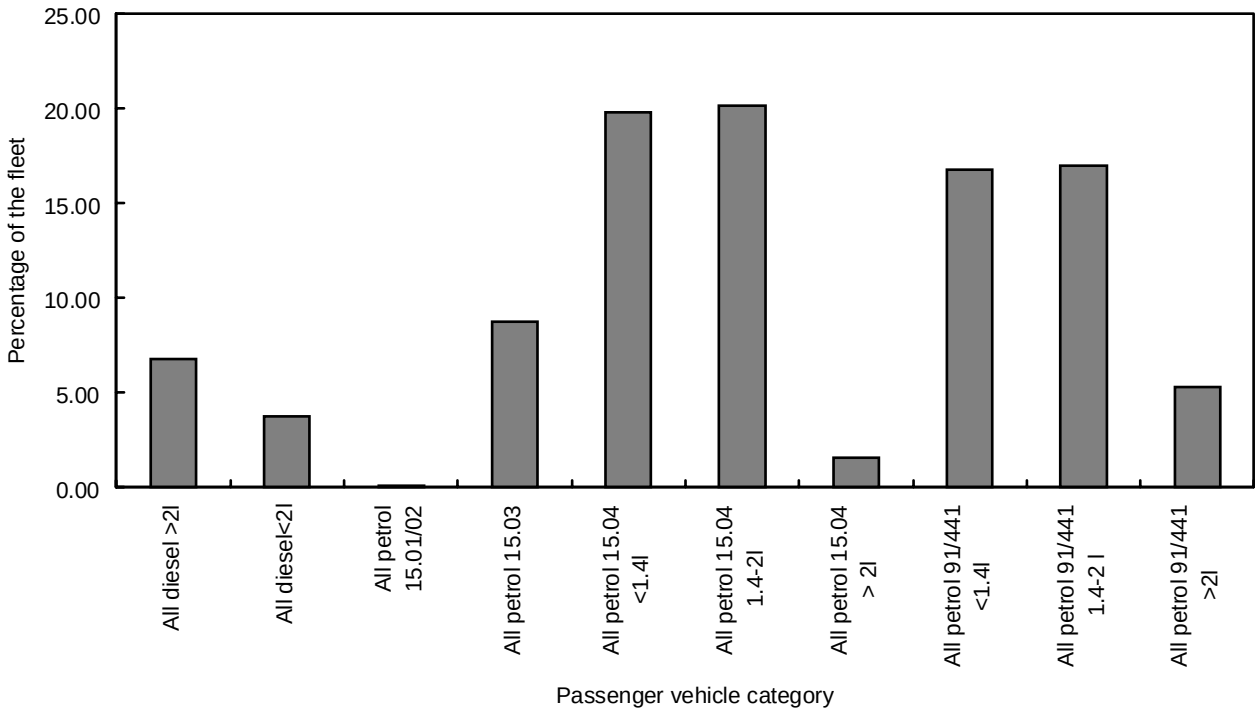

Figure A2 Distribution of passenger cars in the national fleet

Appendix B: Cost-benefit analysis

B1 Main trial

Annual VOC savings = £193 * 24 = £4,632
Annual time savings = £296 * 24 = £7,104
Annual fuel savings = £158.85 * 24 = £3,812.40

Year	Capital costs (£)	Main-tenance costs (£)	Total costs (£)	Benefits (fuel+ VOC+ time) (£)	Present value (discounted at 6%) Costs (£)	Present value (discounted at 6%) Benefits (£)
1	41,832		41,832	15,537	41,832	15,537
2		2,092	2,092	15,537	1,973	14,651
3		2,092	2,092	15,537	1,862	13,828
4		2,092	2,092	15,537	1,757	13,051
5		2,092	2,092	15,537	1,657	12,305

Analysis over a three year period - NPV = -£1,651
EIRR = 2%

Analysis over a five year period - NPV = £20,291
EIRR = 36%

B2 Established teleworkers

Annual VOC savings = £251 * 24 = £6,024
Annual time savings = £417 * 24 = £10,008
Annual fuel savings = £169.88 * 24 = £4,077.12

Year	Capital costs (£)	Main-tenance costs (£)	Total costs (£)	Benefits (fuel+ VOC+ time) (£)	Present value (discounted at 6%) Costs (£)	Present value (discounted at 6%) Benefits (£)
1	41,832		41,832	20,109	41,832	20,109
2		2,092	2,092	20,109	1,973	18,963
3		2,092	2,092	20,109	1,862	17,897
4		2,092	2,092	20,109	1,757	16,892
5		2,092	2,092	20,109	1,657	15,926

Analysis over a three year period - NPV = £11,303
EIRR = 42%

Analysis over a five year period - NPV = £40,706
EIRR = 74%

Abstract

This report describes the evaluation of a trial of teleworking in Hampshire. Teleworking enables employees to work from home or at offices closer to home by using computers and telecommunications. The trial was part of ENTRANCE project.

The teleworking trial aimed to demonstrate energy savings and environmental benefits by enabling some employees to telework on full or part-time basis. Four organisations introduced teleworking for a small number of employees.

The travel behaviour, working practices, opinions and aspirations of the teleworkers were monitored before and after teleworking began. People who had been teleworking for part of their working week for two to four years were also studied. Most worked part of the week at home and part in the office. The report shows the impact on travel by car and other modes, and the resulting reduction in energy consumption and fuel use for travel. The benefits and disbenefits are described from the point of view of employees and employers. Substantial reductions in weekly car mileage were identified, and thus the objectives of the trial were achieved.

Related publications

TRL415 *Monitoring and evaluation of the applications in Hampshire* by Transport Research Laboratory, Transportation Research Group (Southampton University) and University of Portsmouth. (*In production*)

TRL413 *Monitoring and evaluation of a public transport priority scheme in Southampton* by Transport Research Laboratory, Transportation Research Group (Southampton University) and University of Portsmouth. 1999 (price £35, code H)

TRL412 *Monitoring and evaluation of the Bikeabout scheme in Portsmouth* by Transport Research Laboratory, Transportation Research Group (Southampton University) and University of Portsmouth. 1999 (price £35, code H)

TRL411 *Monitoring and evaluation of a public transport priority scheme in Eastleigh* by Transport Research Laboratory, Transportation Research Group (Southampton University) and University of Portsmouth. 1999 (price £35, code H)

PR104 *Literature review of short trips* by M Royles. 1995 (price £25, code E)

SR796 *Commuting patterns in Europe: An overview of the literature* by L Pickup and S W Town. 1983 (price £20)

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