Teleworking in the Netherlands: An Evaluation of Changes in Travel Behavior—Further Results

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The first two teleworking experiments in the Netherlands are described, and the results of an analysis of the impact of teleworking on the travel behavior of the participants and their household members during the experiments are presented. The mobility evaluation was designed as a multiple panel with waves at approximately 3-month intervals. The two experiments were analyzed and evaluated separately. Most important was the reduction of commuting trips (−15 percent) found in both experiments. The reduction is somewhat lower than expected on the basis of the percentage of time used for teleworking (18 to 24 percent) due to the freedom given in arranging teleworking time. The first experiment showed a considerable reduction of peak-hour automobile traffic (26 percent), which explains most of the commuting reduction; in the second experiment the reduction of commuting trips was due to fewer bicycle trips and public transport trips in the later waves. Car use was not influenced at all in the second experiment. A final important difference between the results was the lack of mobility effects for the household members in the second experiment. The first experiment indicated a surprising reduction of mobility not only for the teleworkers themselves but also for their household members. This result did not recur in the second experiment. Analysis of the dynamics of the process seems to indicate that a year may be too short a time span for monitoring such an experiment.

The Second Transport Structure Plan (*1*) aims to combat the problems related to an increasing mobility of persons and goods with a comprehensive set of measures. One of those measures is to stimulate teleworking—working at home using computer, modem, and fax. Teleworking involves less commuting and provides workers with the flexibility to make use of the available traffic infrastructure outside of peak hours. The aim formulated in the Structure Plan is to reduce automobile traffic by 5 percent in peak hours by making use of the possibilities provided by telecommunication. According to the Ministry of Transport, ". . . a substantial group of well-educated workers with relatively little leisure time will embrace the opportunities offered for making times and tasks flexible by teleworking, at home or in regional work centres. The expenses related to traffic jams and the rising travel costs will stimulate this development even more." Another conclusion is that ". . . an experiment conducted by the Ministry of Transport will bolster the further adoption of teleworking" (*1*). To evaluate the effects of teleworking, the ministry has set up two small-scale, in-house experiments intended to determine two types of effects.

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First, the operational effects of teleworking were carefully studied, because acceptance of teleworking will in large part depend on the effects it has on the quality and productivity of the completed work and company management aspects. Of course the evaluation of mobility effects is of primary importance in transport policy. The results of this evaluation are the subject of this report. The evaluation was commissioned by the Project Bureau for Integrated Transport Studies and carried out by Hague Consulting Group (*2,3*). The goal of the evaluation was to trace changes in

- The number of trips for both commuting and other reasons,
- Times of transportation (peak and off-peak hours),
- The days of travel (workday versus weekend), and
- The choice of mode (car, public transport, and bicycle).

The evaluation was directed at both the teleworkers and their household members with the aim of determining direct as well as possible indirect effects.

ORGANIZATION OF THE TELEWORKING EXPERIMENTS

For both teleworking experiments a total of 60 participants were recruited, all employees of the Ministry of Transport. The 30 participants in the first experiment were selected from three departments based in Amsterdam, The Hague, and Rotterdam. All participants in the second experiment were employed in the same department in Rijswijk, a small town bordering The Hague.

The selection of the employees was based on the following criteria:

- The employee's work is suitable for teleworking and colleagues and supervisor agree to the experiment;
- All levels within the organization are represented in the experiment;
- The employee is willing to work a minimum of 20 percent and a maximum of 60 percent at home, the time to be organized at the teleworker's discretion;
- The employee is committed to participating in all training sessions and evaluations connected with the experiment; and
- In the first experiment, commuting is done by car, preferably over long distances.

The selection was geared to maximizing mobility effects and simultaneously minimizing the experimental dropout. A consequence of this selection is that the results of these studies cannot be generalized to other populations.

All participants were provided with a PC, modem, fax, an extra telephone line, and special software. After a training session, the first experiment began on April 1, 1990, and the second on October 1, 1990.

EVALUATION OF MOBILITY EFFECTS

Method

To assess the effects of teleworking on the travel behavior of the participants, a panel was established in which the teleworkers and household members 18 years and older participated. Approximately every 3 months a mobility measurement (wave) was carried out. During the first experiment, five waves were collected (in March, June, September, and November 1990 and March 1991); in the second experiment one wave less (in September and November 1990 and March and June 1991). The setup, a multiwave panel, had a number of advantages over a simpler construction. First, the experimental group was very small. Repeated measurements from this group can be combined for analysis, thus mimicking a larger group. Second, analysis of the waves separately can provide insight into the dynamics of a change. Moreover, a panel setup is extremely suitable for measuring changes in a population that, in principle, remains unchanged.

No control group was established for this study. The expectation was that a control group, required to fill in a large number of forms without being "rewarded" with teleworking, would be substantially less motivated in participating in the evaluations and thus would obscure rather than clarify the results.

Survey Instrument

The mobility data were collected using a self-administered 7-day travel diary composed of two parts. The first part included personal questions, and the second consisted of a series of questions per trip. The personal questions dealt with age, gender, possession of driver's license, and ownership of means of transportation. The trip-related questions included date, origin, origin activity, time of departure, destination, destination activity, time of arrival, transportation mode (chain of up to seven modes), estimated total distance, and, if a car was used, the occupancy.

Survey Procedure

Both groups of 30 households were divided into six groups of approximately 5 households. Each group would begin a wave on a predetermined day of the week (Monday through Saturday). Thus, the procedure was carried out according to a staggered method to ensure that each weekday was equally well represented in the data. The participants were asked to record each trip during the following 7 days in the travel diary, so that each wave lasted a total of 2 weeks.

To maximize the response for all waves, the participants were provided with a great deal of information and received a personal letter before each wave. In addition, on the evening before their designated starting date, each household was contacted by telephone. This contact was mainly a reminder of the correct starting date and in later waves was used to correct ambiguities in previous diaries, but participants could also ask questions, and household members could be given extra motivation. The travel diaries were returned in prestamped addressed envelopes. Reminders were carried out by telephone 14 days after each wave.

Data Entry and Analysis

Upon receipt, each travel diary was checked, and in the case of unclear data the respondent was consulted. The data were entered chronologically for each travel diary with the use of a program containing checks for inconsistencies. A number of derived variables were added. Next, the mobility data were aggregated for each respondent according to number of trips and the total kilometers traveled, broken down by the following criteria:

- Time of day (peak versus off-peak),
- Type of day (workday versus weekend),
- Purpose (commuting, business related, and other reasons), and
- Main means of transport [public transport, car (driver), car (passenger), bicycle, and other].

For each wave a separate data set was constructed with 15 trip categories, not all mutually exclusive. Considering the modest scope of the experiment, a further segmentation was not possible. The data from subsequent waves were then matched for each person to the mobility data from the first wave. In this matching of wave pairs, only those households were included that had experienced no unusual circumstances during either wave (usable diaries). This means that only mobility patterns were compared for those respondents who had participated in the first wave and had not moved, changed work, been ill, had a baby, and so forth in the later wave. If one household member had been ill, the whole household was deleted from the analysis on the assumption that the other members might change their mobility pattern to compensate.

For the analysis of the pattern of mobility effects, each wave pair comparison was tested separately for each segment for changes in frequency and distance traveled. To determine the average mobility effects, the wave pair comparisons were combined and analyzed for each segment using a series of pairwise *t*-tests. Pairwise *t*-tests were used because they are extremely efficient in testing for differences between two related samples and make it possible to assess not only the direction of differences but also their size and confidence interval. However, the distribution of trip frequency is not normal and strictly speaking would require a nonparametric testing method. Therefore, in addition to a series of pairwise *t*-tests, an analogous series of Wilcoxon signed ranks tests was carried out. The results of both analyses were nearly identical and for the rest of the study the pairwise *t*-test was retained.

Response and Mobility

The first experiment was launched on April 1, 1990, and the second experiment began 6 months later on October 1, 1990. Each experiment was preceded by the first wave, which served as the basis for an evaluation of the changes. For practical reasons the waves for the two experiments ran parallel as much as possible. Table 1 gives the response, which is unusually high (almost 100 percent).

More than half of all households consisted of families with one or more children (58 percent), and 12 percent of all teleworkers lived alone. The first group included fewer families and more single persons than the second group. Only two households (3 percent) did not own a car, more than 70 percent of the households had one car, and one household (1.5 percent) had three cars.

In both experiments the experimental group was 5 to 8 percent more mobile than the average person in the Netherlands (*4*). Compared with the national statistics, the panel members of the first group traveled more than double the distance an average person in the Netherlands travels in a day. The second group also covered 60 percent more kilometers. The commuting distance in particular was greater (3 to 4 times), and the greatest distance was covered by car drivers (1.5 to 2.5 times). The differences were primarily caused by teleworkers and are a logical consequence of the selection criteria.

ANALYSIS OF MOBILITY EFFECTS

In this section the results of the two experiments will be discussed. For the first analysis, all the wave pair data are pooled per experiment. The pooled sample becomes larger and, by extension, the statistical precision of the tests becomes greater. Underlying this procedure is the assumption that all respondents are independent—in reality this is not the case—resulting in an overestimation of the *t*-values. The results of this first pooled analysis prompted a short evaluative survey, which is also treated.

The third analysis is based on a series of single wave pair comparisons. In a number of graphs the dynamics of the change process are visualized. Because of the changing comparison group per wave, all changes in trip frequency are calculated relative to an indexed base trip frequency (100 percent). The statistical results of this analysis are available on request (*1,2*). For each wave comparison the group is small, and therefore the precision of the statistics is lower, but because all respondents are, in fact, independent, the *t*-values are correct.

Average Mobility Effects

Table 2 gives the result of the analysis of the pooled wave pairs. In both experiments the mobility of teleworkers decreased the most. The number of commuting trips decreased by 15 percent. In contrast to the first experiment, in which the use of the car decreased sharply, the reduction in commuting trips in the second experiment is explained for 83 percent by less public transport and bicycle trips, whereas travel by car was not reduced at all.

In both experiments the reduction is distributed equally over movements in peak and off-peak periods. Travel during the weekend, which revealed a marked decline in the first experiment, did not change in the second experiment under the influence of teleworking. Moreover, in the second experiment longer trips were made during the weekends.

The first experiment indicated a significant reduction in the mobility of household members. This result is totally absent in the second experiment.

Short Evaluative Survey

In the first teleworking experiment the commuting mobility of the teleworkers was reduced significantly and all other purposes showed a lower mobility. Also the household members displayed a lower mobility. In an effort to explain this finding, a short evaluative survey was carried out. In this survey all respondents were asked to describe their experiences with teleworking (their own or that of their household member). Teleworkers and their family members were all very positive in their evaluation. All hoped for a continuation of the experiment. The teleworkers had not perceived any change in their own mobility besides the elimination of certain commuting trips; neither had they noticed a change in the mobility of the family due to their teleworking. The household members were of a similar opinion. The panel members had not used teleworking for streamlining activities or major rearrangement of tasks.

Pattern of Mobility Effects

On the basis of the single pre-and postcomparisons, graphs were produced providing insight into the pattern of change.

TABLE 1 Response to Mobility Evaluation Study of Two Telework Experiments

Month 1990-1991	First Teleworking Experiment			Second Teleworking Experiment		
	Wave	Response	Usable diaries	Wave	Response	Usable diaries
March	1	60 (100%)				
June	2	62 (100%)	47 (76%)			
September	3	58 (100%)	45 (78%)	1	62 (95%)	
November	4	58 (100%)	48 (83%)	2	63 (97%)	47 (72%)
March	5	56 (97%)	48 (83%)	3	58 (91%)	42 (74%)
June				4	60 (95%)	44 (70%)

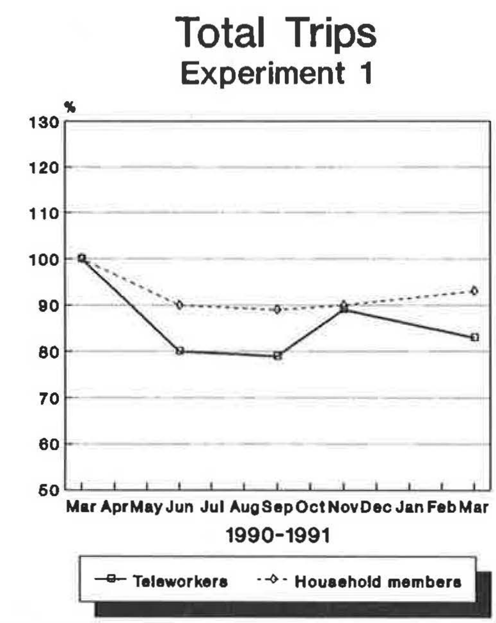
TABLE 2 Results of Average Effects Analysis of Telework Experiments

	First Teleworking Experiment (n=188)				Second Teleworking Experiment (n=133)			
	trips[a]		distance[a]		trips		distance	
Segment	Tw[b]	Hm[b]	Tw	Hm	Tw	Hm	Tw	Hm
Total	-17%	-9%	-16%	--[c]	-10%	--	-14%	--
Peak	-19%	--	-26%	--	-11%	--	-22%	--
Off-Peak	-15%	-12%	--	--	-10%	--	--	--
Weekday	-18%	--	-18%	--	-13%	--	-25%	--
Weekend	-13%	-18%	--	--	--	--	+73%	+137%
Commuting	-15%	--	--	--	-15%	--	-16%	--
Business	-33%	--	-49%	+27%	--	--	--	--
Other	-14%	-13%	--	--	-15%	--	--	+46%
Public Transport	-18%	--	--	--	-63%[c]	--	-55%[c]	--
Car (driver)	-19%	--	-19%	--	--	--	--	--
Car (pass.)	-27%	-19%	--	--	--	--	--	--
Bicycle	-31%[c]	--	--	+35%[c]	-35%	--	-40%	--
Other	--	--	+55%[c]	--	--	--	+75%	--
Car/Peak	-26%	--	-34%	--	--	--	--	+34%
Car/ Off Peak	-17%	--	--	--	--	--	--	--

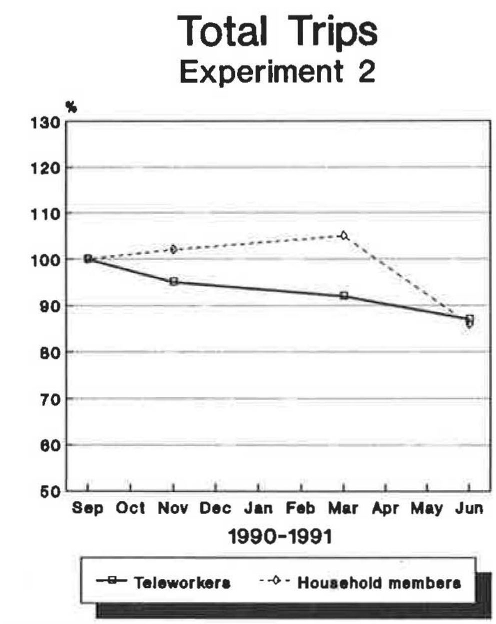
[a] Trips and Distance refer to trip frequency and total distance travelled per segment.
[b] Tw and Hm refer to Teleworkers and Household members.
[c] In absolute terms the change is small.
-- Change is not significant on a 10% level.

The graphs have been corrected for seasonal influences on the basis of the averaged monthly mobility over 5 years (1986 to 1990).

Figure 1 shows the observed total number of trips made by teleworkers and household members per wave pair for both experiments. The difference between the mobility of the teleworkers is immediately apparent. The mobility change in the first experiment is larger than in the second experiment. Even more obvious is the difference in behavior of the household members. In the first experiment the household members display a lower mobility, whereas in the second experiment the mobility of household members only starts to decrease in



Source: HCG 1991



Source: HCG 1991

FIGURE 1 Change in the total number of trips for teleworkers and household members.

the last wave. The latter may indicate that 1 year is too short a period to monitor for secondary effects.

In comparing mobility by purpose (Figures 2 and 3), it becomes clear that in the second experiment the reduction in commute trips is fairly constant with a slight rise in the last wave. In the first experiment the dynamics were slightly different. Initially the teleworkers enthusiastically started working at home as much as they could; however, for a variety of reasons they returned to working in the office more (5). The decline leveled off at −10 percent in the later waves. In both experiments the mobility of household members is characterized by much larger spreads expressed in clearly larger confidence intervals and an erratic pattern. The seemingly large increase in commuting trips made by household members in June 1991 is not a result of increased employment, but rather a result of a low number of observations for this purpose.

In Figures 4 and 5, the difference in the results between both experiments is clear. Figure 4 shows the changes in mode for the first experiment. Here the decline of car use is very

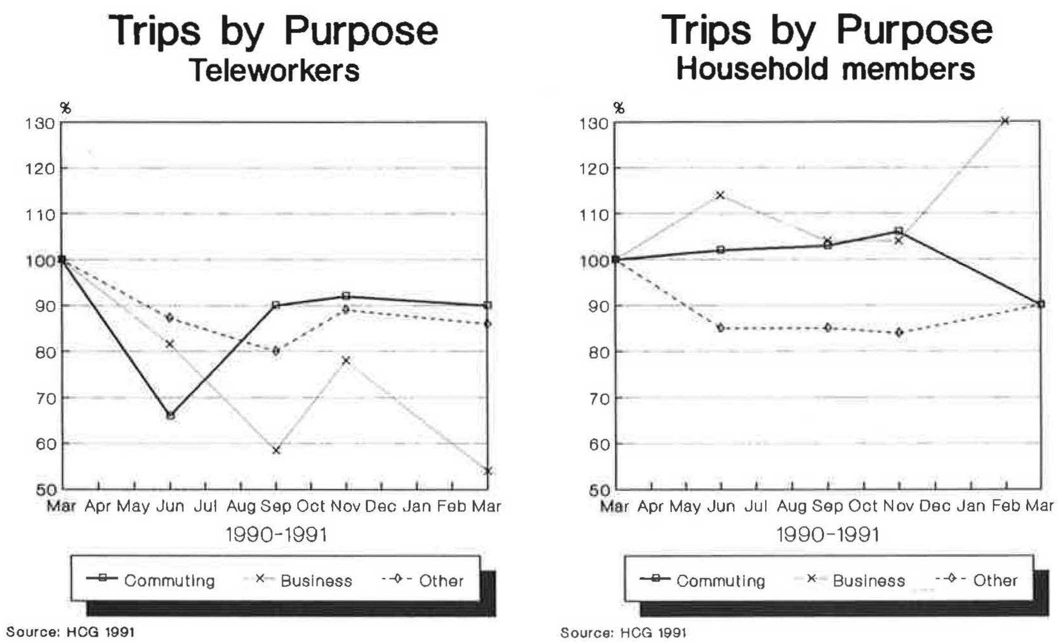


FIGURE 2 Changes in the number of trips by purpose (Teleworking 1).

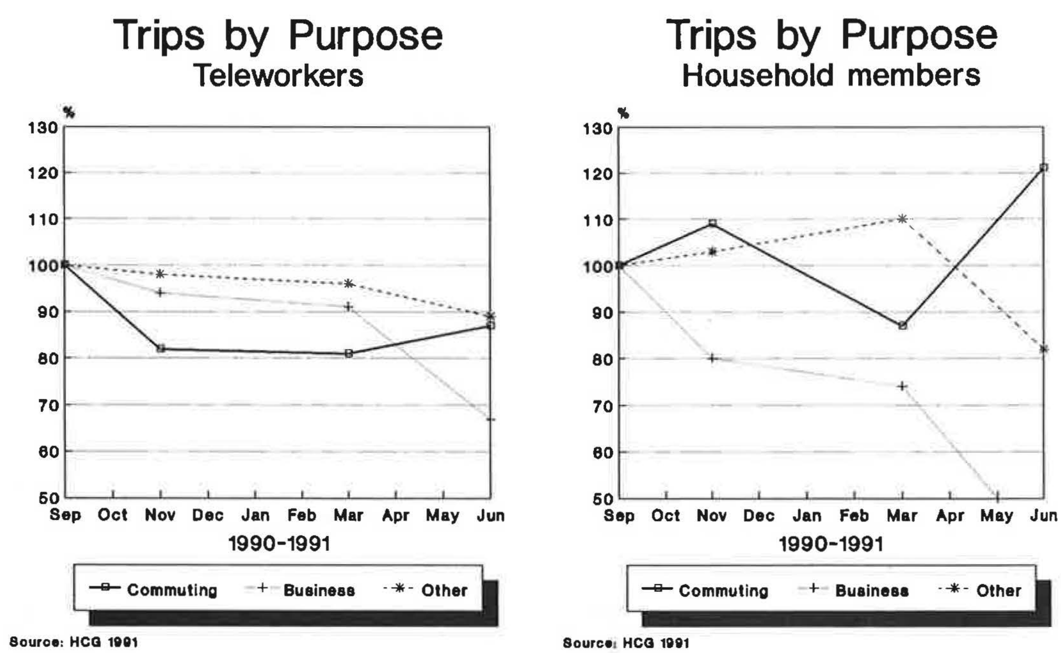


FIGURE 3 Changes in the number of trips by purpose (Teleworking 2).

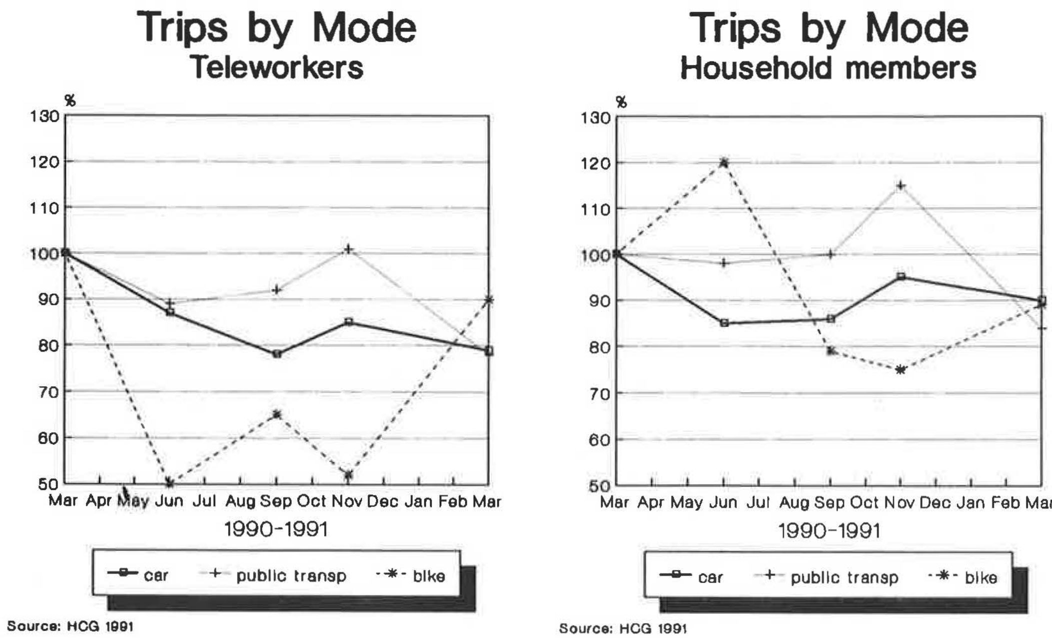


FIGURE 4 Change in the number of trips according to means of transportation (Teleworking 1).

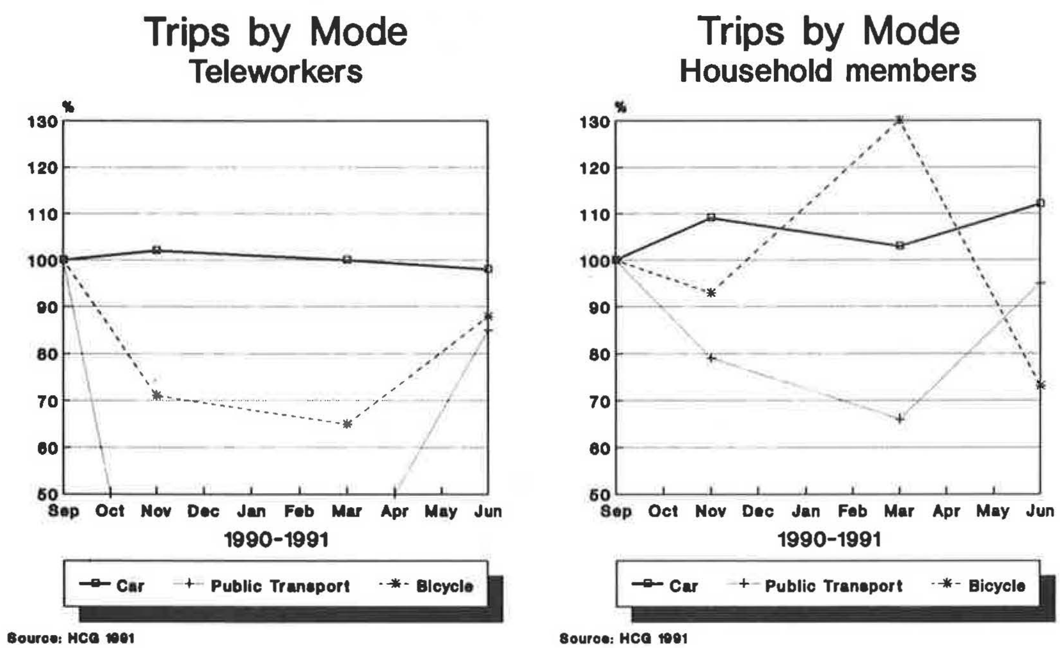


FIGURE 5 Change in the number of trips according to means of transportation (Teleworking 2).

obvious. By the second wave it had diminished by approximately 20 percent for the teleworkers and approximately 10 percent for the household members. In Figure 5, which shows the same changes for the second experiment, one can see that the teleworker's car use remains almost constant at the original level. The reduced mobility of the teleworkers in this experiment is explained almost totally by the elimination of public transport and bicycle trips. The mode pattern for the household members displays an even more erratic pattern after seasonal correction than before. The large increase in bicycle trips in March and the almost equally large reduction in June are apparent. This pattern emerged more clearly after seasonal correction and is due to an unusually warm March, leading to more trips by bicycle, and subsequently the coldest and wettest June in more than a century, leading to more transit use.

ANNOTATIONS

These results, encouraging as they may appear, call for careful evaluation. They may be in part the result of the experiment.

Because of the rigorous selection, especially in the case of the first experiment, these experiments are more likely to indicate a maximum result than an average one. This bias may be compounded, in the case of the first experiment, by an awareness of the importance of a reduction of mobility for the continuation of the experiment.

Part of the results may be explained by the measurement method. To check the influence of the so-called panel effects, a number of checks of the diaries were undertaken. We found no evidence that the observed reduction of mobility is due to trip underreporting in later measurements. There was no significant increase in average number of mistakes per trip, tripless days, or missing (return) trips indicating panel fatigue over the measurements. The reported mobility was almost level over all measurement days in all but one measurement. This feature may indicate almost no panel fatigue within each measurement and may also support the assumption of high motivation on the respondents' part to participate fully in all evaluations, adding credibility to the results. In the base measurement of the first teleworking experiment, a slightly higher mobility was reported on only the first measurement day. This deviation explains in part the household members' observed reduced mobility in the first experiment, while only slightly reducing the mobility effects for the teleworkers in the first experiment without changing the results of the analysis significantly.

We also tested whether trip chaining explained part of the observed mobility effect. Perhaps respondents had streamlined their activities and merely rearranged their trips, substituting simple home-activity-home chains with longer and more complicated ones. In that case part of the mobility effects may be due to elimination of trips. However, household members did not increase their trip chain length. Teleworkers even reduced the average chain length by 12 percent. This means that trip chaining did not add to the mobility effects of teleworking. Furthermore, during the experiments, no large-scale changes in policy were recorded that could account for a part of the mobility change. In fact the average (car) mobility in the Netherlands is still rising.

And finally, we analyzed whether within the group of teleworkers there were other characteristics that could give more insight into the mobility effects of teleworking. This analysis clearly indicated that commuting distance is important in ascertaining the effects of teleworking. Car use, especially during peak hours, is maximally reduced (20 to 40 percent) for commuting distances of 20 km or more. Shorter commuting distances lead to only slightly fewer commuting trips, and even then usually the bicycle trips are eliminated. Travel time, by the nature of things correlated with the distance, shows an even more clear pattern. Commuting times of 20 to 60 min show a clear reduction of commuting trips (20 to 30 percent), whereas even longer commute times also show a reduction in the low number of business-related trips.

DISCUSSION OF RESULTS

In a number of previous European studies, expected effects of telematics on mobility have been brought forward. Most expectations can be summarized with the phrase "some substitution of commuting traffic, but generation of mobility for other purposes and [most important] increased use of the now available household car" (*6–8*). These studies are for the rest mostly concerned with estimating the number of jobs suitable for teleworking. The results of both experiments treated here indicate that teleworking can indeed contribute to a reduction of the number of commuting trips. Furthermore, it contributes to distributing the use of the infrastructure, which is particularly scarce during peak hours. Finally, we found no indication of increased car use by household members.

A second comparison can be made with other evaluation studies. At this time only one similar experiment in California is known to us (*9*). The results of both Dutch and the California experiments are very similar. In California, teleworking reduces the number of commuting trips, and no new trips are generated. Also a marked reduction in trip frequency for nonwork purposes is found. However, in the California case there are some indications that the reduced mobility of the household members is partly due to trip underreporting (*10*). In the Dutch experiments there is no indication of trip underreporting. An extra survey, specifically undertaken to find an explanation for the reduced mobility of the household members, gave no insight into this phenomenon. However, during the selection of the participants for the first experiment, special attention was given to the importance of reducing car mobility. Perhaps this emphasis resulted in an increased awareness and subsequent reluctance to use the household car.

The experiments clearly indicate that teleworking can contribute significantly to reducing commuting traffic, yielding an average of 15 percent fewer commuting trips from 20 percent restriction-free teleworking time. However, in situations where there are competing modes, as in the Netherlands, the benefit of teleworking in reducing car traffic is less straightforward. The possibility of working at home will especially affect workers with relatively large resistances in their commuting trips. In the first experiment most participants traveled to work on the highways. They probably encountered resistance regularly in the form of peak-hour congestion. In the second experiment most commute trips were also made by car, but usually the highways could be avoided. It is very possible that this group of teleworkers met relatively little peak-hour congestion. On the other hand the work location in Rijswijk is difficult to reach by public transport. The results clearly indicate that precisely these public transport trips were almost entirely eliminated. Furthermore, traveling by bicycle has a higher resistance, and such trips also tended to be canceled in favor of more comfortable trips by car. This means that work location, its facilities, and commuting travel time, including time lost in congestion, are important aspects determining the benefits of teleworking for the reduction of car mobility.

Possibly, the effects of teleworking in particular reducing car traffic will increase with larger commuting resistances (i.e., longer distances or travel times). Commuters who have a large commute mobility may be traveling above their preferred mobility budget, and therefore when commute trips are eliminated there is little chance of generating more trips for other purposes. Under these circumstances maximum effects are to be expected. The impression is that the selection of the participants, in particular the first Dutch experiment, led to including almost exclusively commuters who operate above their travel budget. The mobility changes found in these experiments are more probably maximum than average effects.

Finally, a warning is appropriate: introducing more flexible work hours and work locations, for instance through teleworking, may result in workers accepting even longer commute distances for the remaining commutes. This long-term change might eventually even cancel out the initial positive traffic and environmental effects. In this sense the possibilities created by teleworking are comparable with those created by mass motorization. These long-term effects are not evaluated in this study.

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