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ASSESSING THE IMPACT OF ADVANCED TELECOMMUNICATIONS ON WORK-RELATED TRAVEL

TOM VAN VUREN
Hague Consulting Group
36 Regent Street
CAMBRIDGE CB2 1DB ENGLAND

ANDY LAKE
The Home Office Partnership
St Johns Innovation Centre
Cowley Road
CAMBRIDGE CB4 4WS ENGLAND

Abstract

Research on the likely travel impacts of teleworking has generally concentrated on narrow, self-selected groups of existing tele-workers, unlikely to be representative of the whole working population. Also, to make teleworking happen, the benefits to the employers must be clear. Most teleworking initiatives are generated by the advantages they confer on a business, rather than for environmental reasons. Then, not only commuting travel, but all travel in the course of work must be assessed. Changes in organisational structure and a range of advanced telecommunications (e.g. teleconferencing) are relevant . The paper aims to provide a first insight in the types of work or worker most successfully targeted by telecommunications programmes, in terms of potential travel reduction (to, from and within work). A classification of jobs is made, based on characteristics with respect to the amount of field work, solitary work, team interface and meetings (frequency, location, urgency and duration), and the potential for process change within the job. These findings are used as the basis for quantification of possible transport and environmental impacts in a congested city (Cambridge).

INTRODUCTION

Most organisations will not substantially reorganise the way they work just to reduce the amount of commuting done by their employees. Nor, voluntarily, are most organisations likely to change the way they work for the sake of the environment. If tangible reductions are to be made in the amount of traffic on the roads, they are more likely to be achieved if large organisations are on board with the process. And if remote working is a potential factor in achieving this reduction, the effects are more likely to be significant if major employers change the way they work, rather than individuals.

Organisations will change the way they work if there are identifiable business benefits[i]. Promoting sustainability is likely to be a secondary consideration. The study reported here (Home Office Partnership, 1997) therefore examined the potential for a large employer to change the way people work, considering work patterns successfully introduced by other large organisations. It focused on the types of work most amenable to being carried out using new information and communication technologies (ICT), and most capable of achieving a reduced need to travel. Various "remote working" scenarios were considered and different levels of potential for location independent working were assigned to categories of work identified.

One difference between this and many other studies is that we have not sought to develop a prescriptive definition of teleworking. For example, a number of surveys only count people as teleworkers if they work more than 50% of the time from home. For our purposes, which have a practical focus, any amount of time spent working away from the normal place of work has a transport effect. So even if the type of work someone does only allows one or two days per month working elsewhere, there will nonetheless be a quantifiable traffic effect.

In essence the study is looking at 4 things:

- the ways in which people's work can change using new ICT
- potential reductions in commute traffic
- potential reductions in business travel
- potential reductions in emissions

From this we highlight issues for practice, and make a number of recommendations.

REMOTE WORKING ANALYSIS

Broadly defined "teleworking" options include home-based working, working at telecentres or satellite offices, teleworking between existing sites, and using information and communication technologies for virtual meetings (with clients, partners, other departments etc) and for remote diagnostics, remote monitoring etc. of sites. The approach taken in the study was to assess one major employer which employs a wide variety of work types, in this case a British County Council with some 19,000 staff. School-based teachers, residential social workers and fire-fighters were assumed to have no significant potential for location independent working.

Thus the study focused for its analysis on:

- headquarters staff;
- fieldworking staff, based either at the headquarters site or in local offices/depots based in the Cambridge traffic model area.

This accounted for some 2,300 staff, although it is anticipated that the characteristics of their work will be shared by a further 5,000 staff at various sites around the county. The work and travel behaviour of staff were observed via the following mechanisms:

- initial cross-departmental **focus groups** to examine the issues involved in establishing cross-departmental work types for the analysis
- **structured interviews** with senior managers, covering all work areas of the organisation
- **structured interviews** with middle managers in the larger departments
- a targeted **work location survey**, which identified types of work undertaken, their current location, numbers of hours the tasks were performed, where the tasks were located, time spent in travel to perform particular tasks, and an assessment by the respondent of whether/what percentage of the task could be performed at an alternative location given access to adequate resources
- a **staff questionnaire** to establish commuting and business travel patterns, and to verify some of the findings from the work location survey

The study was a limited, exploratory study funded under the Seedcorn programme of the Department of the Environment, Transport and the Regions. In that sense it marks a beginning, rather than an end to the research. Our location-independence potential (LIP) analysis of work types therefore is not to be considered an exhaustive examination of all types of work at the test site.

Three broad bands of work, Support, Service Delivery, and Management were identified, and a range of sub-categories for each of them. In total there were 25 sub-categories. It is to be remembered that these represent types of **work**, rather than of **worker**. Any given worker is likely to exhibit more than one of the work-type sub-categories. For example, a field worker might spend a considerable proportion of his or her time on a face-to-face basis meeting with clients or partner organisations. The analysis showed, however, that people falling into the field worker category also tended to spend a significant amount of time at the base office doing writing-up work, or policy development work, or talking on the telephone. The types of work done in this way are also common to many people who are not field workers. Such work is in many cases more amenable to being done in alternative locations.

One issue faced in the analysis is where (on a self-reporting basis) respondents to the work location survey made different assessments of the amount of work which they felt could be performed elsewhere. In such instances, judgements had to be made, based on information from the structured interviews and knowledge of the persons job. The analysis was also informed to some extent by the investigators' knowledge and experience of the successful implementation of new ways of working in other organisations. The self-assessment of the "location independence potential", then, acted as a guide but not a determining factor. It was, however, the major factor in determining the lower level of the potential.

To a certain extent the upper limit is a matter of best judgement, based upon "best case" instances identified. This is a very difficult area for objective analysis for a number of reasons:

- the potential depends to some extent on the choice of teleworking option, and the telecommunications technologies involved;
- these choices would, in reality, be influenced by how managers in the organisation perceived and assessed the potential benefits in relation to other objectives such as property reduction, decentralisation of services, greater customer focus, etc.;
- the levels of coercion and/or incentives that might be applied in determining where employees should work;

- there is a knock-on effect from implementing new ways of working: for example if a support worker's location is currently determined by the need for physical proximity with management or service deliverers, then if the latter operate on a location independent basis then the locational requirements for their support workers can also be expected to change.

Having said this, the estimates, including the upper figures, tend to be conservative in comparison to some of the more high profile teleworking implementations in the private sector, or the writings of the teleworking "evangelists" or "gurus" who argue the merits of moving to pretty much 100% teleworking for vast numbers of workers.

Table 1: Support work sub-types: potential for location independence

Code	Supporting who/what	Doing what (eg)	% of work type which could be done remotely	Realising the benefits of remote working
S1	individuals eg managers, specific teams	WP, typing	60-100%	Home working or working from conveniently-sited telecentre, using PC, telephone, possibly network access
S2	Individuals eg managers, specific teams	Liaison role (enquiries, arranging meetings etc)	20-40%	Home working or working from conveniently-sited telecentre, using PC, telephone, possibly network access for email, diary sharing
S3	Office support	Filing, ordering, distributing information	0-20%	Some work could be done remotely, particularly where using telephone, information system
S4	Process eg for service delivery	Low volume data input, monitoring financial information	40-80%	Home working or working from conveniently-sited telecentre, using PC, telephone, possibly network access
S5	Public/face-to-face	Receive visitors, hospitality	0%	Centre-based, but could be in a local office or telecentre?
S6	Public/ electronic	Handle phone/email queries	80-100%	Working from telecentre, using PC, telephone, possibly network access for email, diary sharing, email handling
S7	High volume process/ electronic	Data entry	80-100%	Home working or working from conveniently-sited telecentre, using PC, telephone, possibly network access
S8	High volume process/physical presence	Handling objects eg money, post	0%	Centre-based, but could be in a local office or telecentre?

Each sub-category, on the basis of the analysis, was given an upper and lower potential for location independent working. In some cases (e.g. S5, public interface, face to face support work, for example a receptionist) the potential was 0%. For others the potential was much higher (e.g. for category S6, public interface, using telephone, the potential was 80-100%).

Tables 1-3 outline the taxonomy of work which was developed relating current work types to the potential for working in a location independent manner. However, because of the numbers involved it was decided for the traffic analysis to work within the broader bands of Support, Delivery and Management. Table 4 indicates the location independence potential of work in each broad band.

It is to be remembered that these figures mask the wider fluctuations in potential between types of work. Also, in terms of the sub-categories, individual workers will in most cases combine various types of work. The combination of tasks which separately have differing levels of remote working potential has on the whole a tendency to reduce the potential for flexibility in location.

Table 2: Delivery work sub-types: potential for location independence

Code	Service delivered involves (key characteristic)	Doing what (eg)	% of work type which could be done remotely	Realising the benefits of remote working
D1	High people interaction	Meetings with external clients	20-40%	Some meetings substituted by videoconferencing, report writing can be done at home/telecentre
D2	High people interaction	Meetings with colleagues, collaborative work	40-60%	Some meetings substituted by email, report writing can be done at home/telecentre
D3	High people interaction	Meetings with internal clients	20-40%	Some meetings substituted by videoconferencing, report writing can be done at home/telecentre
D4	High people interaction	Meetings - interagency	40-60%	Some face-to-face essential, longer term projects can be supported by ICTs, EDI, extranets, etc
D5	Site-specific	Diagnostic, planning, monitoring	20-40%	Revisits could be reduced through use of ICT, some diagnostics can be performed remotely
D6	Site-specific	Hands-on at site	0-20%	Use home as a base, mobile working supported by phone, modem link
D7	Site-specific	Hands-on at site - equipment movable	0-20%	Use home as a base, mobile working supported by phone, modem link
D8	Knowledge-based/policy	Planning, report-writing, review and committee work	80-100%	Home/centre-based, can work anywhere, anytime, using PC, network access, electronic storage
D9	Knowledge-based/technical skills	Graphics work, work with GIS, databases	20-60%	With adequate bandwidths, work can be done remotely, home/centre-based
D10	Knowledge-based/specialist information	Report-writing, research	0-60%	Potentially high levels of remote working possible
D11	Knowledge-based/specialist advice	Internal requests for legal, H&S, grants etc information	0-60%	Potentially high levels of remote working possible - depends on culture, practice, specialism

TRAVEL IMPACTS ON HOME-TO-WORK TRAVEL

Up till here the analyses have concentrated on the ability of employees to work remotely; now this percentage remote working must be translated into travel impacts on home-to-work travel and business travel. Separate techniques and base data have been used in these assessments. The travel impacts on home-to-work travel have been estimated using the existing traffic assignment model of Cambridge, amended for the change in travel demand through remote working. This network model covers in detail for 1996 the area within the City boundaries (including two strategic high volume roads passing the City: the A14 and the M11) and in less detail the immediately surrounding area. It distinguishes travel demand in three time periods: the 8-9 AM peak period, the 5-6 PM peak period and an off peak period containing the remaining 14 hours of the overall 16 hour model (6 AM - 10 PM).

Our analyses concentrate on the travel mode "car alone" for the following reasons:

- the network model does not distinguish public transport or slow modes;
- the effects of passenger demand changes on public transport vehicle miles and emissions is not straightforward to estimate;
- the questionnaire distinguishes "car alone" from "car with others", rather than "car driver" and "car passenger". Ignoring the "car with others" provides a lower estimate of the possible effects of remote working practices[ii].

Table 3: Management work sub-types: potential for location independence

Code	Managing who/ what	Doing what (eg)	% of work type which could be done remotely	Realising the benefits of remote working
M1	Supervising people/planning	Small numbers of staff, single service area, one site	20-40%	Some meetings substituted by email, report writing can be done at home/telecentre
M2	Supervising people/planning	Small numbers of staff, single service area, wide geographic distribution	40-60%	Some meetings substituted by email, videoconferencing, create 'telepresence'
M3	Supervising people/planning	Large numbers of staff, possibly different service areas, one site	20-60%	Create 'telepresence' through high access to PCs, regular use of emails, videoconferencing
M4	Supervising people/planning	Large numbers of staff, possibly different service areas, wide geographic distribution	60-80%	Create 'telepresence' through high access to PCs, regular use of emails, videoconferencing, extensive use of mobile communications support
M5	Managing resources	Managing property, contracts	40-80%	With links to information systems, assuming security isn't major issue, most work can be done remotely through electronic mediation of work
M6	Ambassador	Significant external role	0-20%	Mobile communications support accessibility and 'instant response'

Table 4: Management work sub-types: potential for location independence

Work category	Proportion which is in principle location independent
Support	5-20%
Delivery (inc. Field Worker)	30-60%
Management	30-50%

The proportion of work time that each person type is able to work remotely has been translated into travel effects assuming two scenarios:

1. on days that the employee can work remotely, half the trips are moved to outside the peak period (i.e. a shift in departure time but the same number of trips);
2. the amount of remote working is translated into the same percentage reduction in home to work trips (i.e. full substitution).

Whereas the former is likely to be an underestimate of possible travel effects, the latter is the upper bound. These effects were calculated for the short and long term, resulting in 4 scenarios altogether. Hence, referring to table 4 and assuming a 5 day work week, in our estimates the telework substitution potential ranges from 5-30% in the short term (0.25-1.5 days), increasing to 60% (3 days) in the future for those workers for whom a teleworking option is applicable. In the United States, on average,

existing teleworkers work from home on 1.2 days per week (Smart Valley Inc, 1996); this figure rises to 1.8 days per week for specific teleworking programs (Rathbone, 1992).

Table 5: Estimated annual reductions in travel time, travel distance and road transport related emissions in four telework scenarios

		short term reduction	long term reduction	short term time shift	long term time shift
AM peak	travel time (veh. hrs)	16700	24080	12000	14100
	travel distance (kms)	13740	144940	-47420	95380
	CO (kg)	2920	5640	1840	3360
	CO_2 (kg)	18860	42040	9680	26600
	NOx (kg)	80	460	-80	260
	HC (kg)	500	960	300	580
	Pb (kg)	4.98	7.20	3.60	4.26
PM peak	travel time (veh. hrs)	14140	29800	5920	17540
	travel distance (kms)	228360	561700	98440	278480
	CO (kg)	2860	7400	1140	3800
	CO_2 (kg)	29320	73280	11220	37100
	NOx (kg)	340	1100	180	500
	HC (kg)	500	1300	200	660
	Pb (kg)	4.26	8.94	1.80	5.28
off peak	travel time (veh. hrs)	620	1320	-380	-700
	travel distance (kms)	44200	92180	-20260	-43020
	CO (kg)	180	420	-140	-240
	CO_2 (kg)	3300	6980	-1640	-3300
	NOx (kg)	60	60	-20	-60
	HC (kg)	40	80	-20	-40
	Pb (kg)	0.18	0.42	-0.12	-0.18
all day	travel time (veh. hrs)	39520	72360	12600	21840
	Travel distance (kms)	860900	1997160	-232620	-228420
	CO (kg)	8300	18920	1020	3800
	CO_2 (kg)	94380	213040	-2060	17500
	NOx (kg)	1260	2400	-180	-80
	HC (kg)	1560	3380	220	680
	Pb (kg)	12	22	4	7

In Table 5 the results of the network analyses are shown, presenting the effects of the four scenarios on travel time, travel distance and emissions for each of the 3 time periods, and the whole day. The figures presented are annual values, assuming 200 working days per year.

Most results are as expected, but some in the departure time shift scenarios appear anomalous (indicated by italics in the table). The main culprit is the short term shift scenario, where the shift of peak travel to the off-peak period results in an estimated increase in travel distance in the AM peak. The relatively small changes in demand compared with the resolution of the network model may be responsible for this effect. This result filters through to some of the emission estimates and the aggregate all-day totals. For this reason we concentrate on the short and long term reduction scenarios in our analyses below (but remember that these are likely to be upper bounds).

The resulting benefits in travel time are in the order of 40,000 - 70,000 hours per year (0.3-0.6% of total travel time in the network[iii], up to 1% of total travel time in the City) in the short and long term respectively, mainly in the two peak periods. In the AM peak this is a reduction of about 1-1.5% (2-3% in the City), in the PM peak slightly more (1-2%, or 2-4% in the City), and in the off-peak negligible, 0.1-0.2% (0.2-0.4% in the City).

Resulting mileage savings are substantial: 800,000 to 2,000,000 km/year, equal to 500,000 - 1,250,000 miles. Percentage-wise, however, this reduction is much less than that for travel time: 0.1-0.3% of the total mileage in the network, but at City level around 1%, mainly effected in the PM peak period.

Calculated reductions in air pollutant emissions are summarised in Table 6. As for travel time and distance savings, these hover in general below the 1% value, if compared with total emissions in the Cambridge network, or in Cambridge City.

An analysis has been carried out of the effects of the long term reduction scenario on travel conditions around Shire Hall, the County Council's Head Office. These are illustrated in Figure 1 for the AM peak. Indeed a reduction in trips arriving at Shire Hall takes place, of the order of 140 trips. This is slightly less than the calculated reduction in Shire Hall bound demand in the AM peak period, but apparently the reduction in congestion in the area releases some trips held up previously in permanent over-capacity queues. In effect, some of the space freed by the telecommuters is filled up with "latent demand" re-routing to more central routes[iv]. This effect is also seen on the surrounding roads. The reduction in car travel demand to Shire Hall results in an overall increase southbound along Castle Street, as this route now becomes a more attractive alternative. The results elsewhere in the vicinity are a mix of flow reductions due to the decreased demand, and flow increases due to re-routed traffic.

Table 6: Effects of reduction scenarios of emissions (short and long term)

	absolute effect	as proportionof network-wide emissions	as proportion of City-wide emissions*
CO (kg)	8300 - 18,900	0.2-0.5%	0.4-0.9%
CO_2 (kg)	94,000 - 213,000	0.2-0.4%	0.3-0.7%
NOx (kg)	1300 - 2400	0.1-0.2%	0.2-0.4%
HC (kg)	1600 - 3400	0.2-0.5%	0.4-0.9%
Pb (kg)	12 - 22	0.3-0.5%	0.5-1.0%

* based on the assumption of linear correlation with travel time

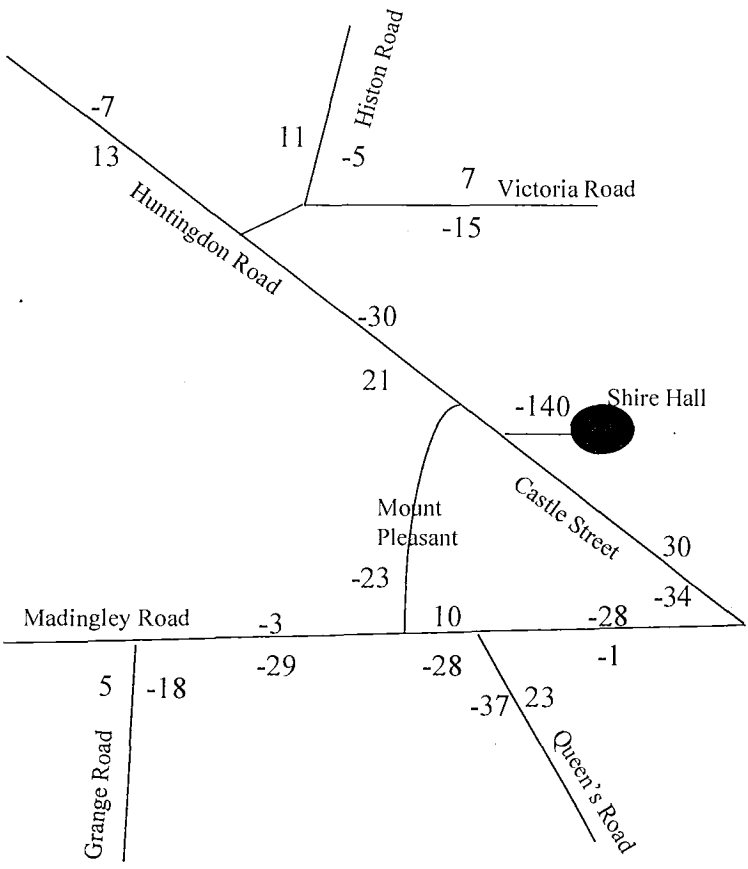

Figure 1: Network impacts of County Council teleworking implementation, AM Peak

TRAVEL IMPACTS ON BUSINESS TRAVEL

The basis for the assessment of possible impacts of advanced telecommunications on business travel in the County Council is the database of mileage claims supplied by its Financial Department.

Table 7: Cambridgeshire County Council mileage reimbursements (1996)

total miles reimbursed	*6.916 M*
home to work	0.025 M
Reorganisation	0.466 M
business – public transport	0.185 M
business – motorcycle	0.002 M
business – bicycle	0.001 M
total business miles by car	**6.236 M**
business as proportion of total reimbursed	90%
car as proportion of total business mileage	97%

After correction for home-to-work travel reimbursements and reorganisation mileage, and excluding public transport, motorcycle and cycle mileage business claims, the remainder has been taken as a full representation of **all** in-work miles by car made on County Council business in 1996. As shown below in Table 7, this represents over 6 million miles, or some 11 million km.

Based on the experience of a similar organisation, Hertfordshire Trading Standards, a possible reduction of 5-15% in business miles has been estimated, in the short and long term respectively. In comparison, Draijer et al (1997) refer to an ECMT study (ECMT, 1983) in which the substitution potential of business trips in two existing organisations is estimated at 13-28%, equal to that of commuting trips. The amount of substitution possible in business travel relates, of course, to the actual reason for the trip; even within the category business travel a wide range of ultimate purposes may be distinguished, each with its specific suitability for remote working. Van Ommeren et al (1997) estimate the distribution shown in Table 8; in that study total substitution potential for business travel is estimated at maximum at 35% (in our case 15%). However, the authors also expect generative effects of advanced telecommunications in business travel, supported by e.g. experience after the introduction of the telephone. This traffic generation might well counterbalance or even outweigh the substitution of business trips, e.g. through increasing trip lengths. These second order effects have been ignored in our analyses.

Table 8: Segmentation of business travel (source: Van Ommeren et al, 1997)

Travel purpose	estimated percentage in business travel
education, conferences	5%
transport of employees	7%
maintenance and repairs	7%
sales and after sales	35%
exploratory meetings[v]	14%
planning meetings	23%
operational meetings	9%
total	100%

No distinction could be made in the potential savings in business mileage for the different person types. Hence, potential savings of 5-15% have been applied across the total number of in-work miles obtained from the County Council database. This implies an annual saving of some 300,000 - 900,000 miles, or some 1500-4500 miles per day (assuming 200 working days).

Emission effects are estimated using the values calculated by the network model in the off-peak period (assuming most business travel to take place in this period), and relating these to miles travelled. Under those assumptions, emission decreases in Cambridgeshire as reported in table 9 may be achieved through the 300,000 - 900,000 annual reduction in business travel miles.

Table 9: Estimated effects on emissions due to reductions in business miles

emittant	absolute effect	as proportion of network-wide emissions
CO (kg)	2400 - 7300	0.1-0.2%
CO_2 (kg)	37,000 - 110,000	0.1-0.2%
NOx (kg)	700 - 2100	0.1-0.2%
HC (kg)	450 - 1350	0.1-0.2%
Pb (kg)	3 - 8	0.1-0.2%

POSSIBLE EFFECTS IF APPLIED THROUGHOUT THE CITY

The figures up till here have shown the possible effects of teleworking introduced within the County Council only on City-wide travel time, mileage and emissions. Now we will estimate the effects if such working practices would be adopted by employers throughout the City. Out of necessity this analysis is crude, and should be viewed as illustrative and speculative. Two cases have been constructed: case A related to the administrative staff in the County Council, plus an estimate of total equivalent employees in the City; and case B related to the whole of the County Council staff, factored up to full existing employment in the City. An important caveat in these calculation is that the County Council staff in the analyses (working within the traffic model boundaries) are not necessarily all located within the City boundaries, whereas the generalisation applies to City workers only. The calculations are based on the following further assumptions (source: County Council Research Group):

case A: administrative staff only

- Cambridgeshire County Council = 7610 administrative staff
- total administrative staff in Cambridge City = (0.5 x (manufacturing + distribution/retail) + financial + other business services + public administration + all other services) = 31,000 equivalent employees
- teleworking potential of overall Cambridge City administrative employees identical to those of the County Council administrative staff
- factor from County Council effects to City effects $31{,}000/7610 \approx 4$

case B: all employees

- Cambridgeshire County Council = 19,000 staff in total
- Cambridge City = 76,500 employees in total
- teleworking potential of overall Cambridge City employees identical to those of full County Council staff
- factor from County Council effects to City effects $76{,}500/19{,}000 \approx 4$

The factor 4 appears relatively robust with respect to employment assumptions (subject to the caveat mentioned above). Further assuming linear trends in the effects of demand reductions on travel time, travel distance and emissions (most likely an overestimate), the values of table 10 are obtained.

Table 10: Estimated annual effects if applied City wide (short and long term)

	home-to-work	Business
travel time (veh.hrs)	160,000 - 300,000	100,000 – 200,000*
travel distance (kms)	3,500,000 - 8,000,000	2,000,000 - 6,000,000
CO (kg)	34,000 - 75,000	10,000 - 30,000
CO_2 (kg)	400,000 – 800,000	140,000 - 450,000
NOx (kg)	5,000 – 10,000	3,000 - 8,000
HC (kg)	6,000 - 14,000	1400 - 5500
Pb (kg)	50 - 100	12 - 32

* = estimated from home-to-work equivalent

Compared with total network model values this would result in a reduction in travel time in the County[vi] of some 2-4%, in travel distance of around 1-2%, and reductions in emissions of similar orders of magnitude. As a proportion of travel within the Cambridge City boundaries these values would be around 4-8% for travel time, and slightly less for distance and emissions, in the short and long term[vii].

DISCUSSION OF MODELLED EFFECTS

All conclusions drawn from the traffic analyses above must be viewed in the light of the assumptions that were necessary to produce quantitative results. These are mainly related to:

- the manner in which a proportion of remote working may be translated into different travel patterns (basically substitution or time shifting). This is affected by the reasons why an employee would choose to telecommute, often more than just the reduction of commuting time and costs, and other constraints that may apply outside the workplace;
- the extent of the network model used and the spatial allocation of travel time, distance and emissions to the City and the County as a whole, plus the subsequent impact on estimated proportional effects of teleworking scenarios on both home to work and business travel;
- the omission of secondary and tertiary effects, such as any longer term effects on e.g. location choice, public transport viability, modal split[viii] and the issue of latent demand;
- the omission of energy impacts at the home (estimated by Mokhtarian et al (1995) at up to 25% of energy savings through the substituted commute);
- the employment assumptions used to generalise the estimates to a City-wide equivalent.

Allowing for these, still a number of interesting general conclusions may be drawn:

- only a proportion of all employees is able to telework, so the overall effect on travel demand is limited, even in scenarios with maximum take up;
- despite the need to stress the **financial** benefits to the organisation, the main **environmental** benefits from the introduction of teleworking are likely to come from reductions in home-to-work mileage (rather than from reduced business miles) - the equivalent values for the effects of advanced telecommunications on business trips are only about 25-50% of those for commuting;
- the way in which remote working will be translated into changing travel patterns is crucial in the resulting effects on congestion and emissions.

Compared to other studies, our findings indicate a limited role for remote working in the battle against congestion and pollution Introduction of teleworking among all employers in Cambridge may cut total travel time, mileage and emissions on workdays by approximately 4-8% in the long term (to put this into perspective, this value is equivalent to about 2-3 years of currently experienced traffic growth).

Another study published in 1996 was commissioned by Autoglass (Freeman 1966). Based on studies such as those by BT and the Henley Centre, it projects reductions in the number of work journeys per year by car as from 328 million in 1996 to 186 million in 2010. This projected reduction of 142 million trips per year represents a reduction amongst individual commuters from 10 trips per week to 5.7 trips per week – a reduction of 43%, implying that the whole population will telework on average just over two days per week. Similar conclusions have been produced in a study commissioned by the another motor industry organisation, the RAC (RAC 1997). The RAC study, based on work by National Economic Research Associates, Herriot Watt University and Critical Research projects that teleworking will by 2007 cut commuter traffic by a fifth, that videoconferencing will cut business travel by a fifth, and that new communications will cut shopping travel by one sixth.

Our study, however, rather than taking a blanket approach, tries to cater for plurality in terms of differing levels of adoption of remote working according to the tasks involved, and also in recognising the impact of organisational choices and culture. In some respects, we are looking at percentage figures not far away from the projections in the Autoglass study: however, our survey of types of employment indicates an average 30% reduction of commute trips achievable by those **for whom at least some remote working is a viable option**. The important point is that this is by no means the *whole* workforce[ix].

In conclusion, teleworking – using advanced communications to replace travel to traditional worksites – should be promoted as part of any integrated transport policy, sitting as part of a basket of demand measures. While the capacity to reduce total mileage may be limited, the capacity to reduce trips to the workplace is significant and should be pursued. In principle, teleworking has the capacity to be promoted positively, as bringing about the possibility of better home/work balance for the employee and reducing costs and increasing efficiency for the employer. It may well be that these personal and organisational benefits are the "selling points", which will have a spin-off transport substitution effect, rather than promoting teleworking for its potential environmental benefits.

ENDNOTES

[i]Employers' motivations for the introduction of teleworking may include improved productivity, employees' demands, reduced labour costs, reduced expenditure on offices, and access to a wider labour market, whilst constraints may be objective (such as the availability of necessary technology and the suitability of the job to be performed remotely) or subjective (such as managerial style, office culture and an unawareness of the advantages) (e.g. Bernardino and Ben Akiva, 1994).

[ii]It may be conjectured that car sharers will have substantially less flexibility to work remotely than solo car drivers anyway, again supporting our decision to leave this group out of the analyses. This assumption is backed up by arguments from Mokhtarian et al (1995).

[iii]Note here that the A14 Trunk Road and M11 Motorway are included in the model, and carry a large volume of through traffic between London, the North, the Midlands and the East Coast Ports. Hence, in the model the proportional effects of possible remote working arrangements by County Council staff on travel patterns in the City are somewhat obscured. A rough analysis estimates that the proportion of modelled traffic within the City produces about 25% of total miles, and 50% of total travel time in the network model.

[iv]other possible forms of latent demand not addressed here may include travellers returning to the peak period after road conditions improve, a modal shift towards the car, and in the longer term locational choice effects.

[v]Exploratory meetings involve many participants, cover various topics and have a long lead time. Planning meetings occur more frequently, involve fewer people, cover few topics in detail and have a shortish lead time. Operational meetings are routine meetings, organised at very short notice and involving only a few people.

[vi]or more precisely, within the network model boundaries.

[vii]In comparison, the EC TELEURBA project undertook sophisticated spatial and socio-economic analyses of workers in the Ile de France, looking both at the origin and destination points of workers and their socio-economic classification, and also drew some conclusions about the impact of teleworking on public transport use. The study projected a 7% reduction in traffic through the use of telework in the Ile de France. (CATRAL 1995).

[viii]Opinions differ on the impact of teleworking on modal split (or conversely, the impact of mode on the willingness to work remotely). A study in San Diego found no change in total mode split before and after introduction of teleworking (Mokhtarian et al, 1995). A study in the Netherlands, however, found that teleworking ("virtual commuting") mainly affected trips by bicycle and public transport, hence not reducing car travel and resulting in a shift in mode split towards the car (Hamer et al, 1991). A possible explanation is that trips by public transport are usually less convenient, and therefore first to be substituted; also argued by Gillespie et al (1995) and Salomon (1994).

[ix]Our estimates for the Cambridge County Council case is that about one-third of the staff are able to work remotely, slightly less than the value quoted by Handy and Mokhtarian (1996), who estimate that 40% of all US workers are potential telecommuters.

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