Environmental Impact of ICT on the Transport Sector

Morten Falch

CMI, Aalborg University Copenhagen, Denmark
falch@cmi.aau.dk

Abstract. This section analyses the environmental impact of ICT. This is done through an analysis on how two specific applications (tele-work and teleshopping) affect transport behavior. These two applications are considered to have a large potential with regard to savings in energy consumption.

Keywords: Green ICT, Tele-work, Teleshopping, Telecommuting, ICT impact on transport.

1 Introduction

The transport sector is both one of the most energy consuming sectors, and also one of the sectors having the largest potential for reduction in negative environmental impacts through use of ICT technologies. In fact environmental concern has been an important factor in driving policies supporting transport related applications of ICT. In particular in the US, ICT has been seen as a way to change a clearly unsustainable trend in the transportation sector without imposing unpopular restrictions on transport.

One of the first studies seeking to calculate the macro impact of ICT on transportation was a study prepared by Arthur D. Little in 1991. The study was very optimistic with regard to the potentials. The executive summary begins as follows: "Can telecommunications help solve America's transportation problems? The answer is definitely yes!"[2]. This answer is based on calculations of the savings, which can be realized through:

- Commuting to work substituted by "telecommuting"
- Shopping, substituted by "teleshopping"
- Business trips, substituted by "teleconferencing"
- Transportation of information, substituted by electronic information transfer.

These calculations estimate that a 33% reduction in transport can be achieved by use of telecommuting. Later studies are far less optimistic regarding the potential savings. One reason is that second order and third order impacts are taken into account (see below). Another is that diffusion of transport reducing ICT applications. Back in the 80's it was expected that as many as 40% of the employees could work as teleworkers [8], but the current level is much below this optimistic figure. Later studies, e.g. [6], have estimated savings at the level of 2-3%. A study of the impact from telecommuting and teleshopping in Denmark estimated the savings to be about 1% of the total person transport [14].

A.M. Hadjiantonis and B. Stiller (Eds.): Telecommunication Economics, LNCS 7216, pp. 126–137, 2012.

This section analyzes the reality of these aspects and reduces some of those uncertainties by introducing visions for different specific applications regarding the three areas; hence it should not to be seen as an analysis of the whole ICT complex. There are four different dimensions of the impact on the environment from the transport sector:

- Overall demand for transport by type
- Demand by transport mode
- Efficiency by mode of transport
- Environmental impact from different modes of transport

While the first two points mainly relate the demand site, points three and four (in particular four) mainly relate to the supply site. First, one must distinguish between freight and person transport as the ICT impact is very different for these two types of transport. For each of these the ICT impact on the overall demand must be assessed. Person transport is usually measured in person kilometers and freight in ton kilometers. ICT can affect the overall demand in various ways: Different applications of ICT may substitute the need for transport for instance by use of tele-work or by use of e-mail instead of surface mail. But ICT may also generate new needs for transport. This impact will most often be realized through indirect effects, for instance through the impact of ICT on globalization. The overall demand for transport includes a wide range of very different transport needs with regard to location, speed, frequency etc. These different needs will often demand use of different modes of transport e.g. train, private car or flight. As the environmental impact from the modes of transport are very different, it is important not to assess the ICT impact on total demand only, but also the ICT impact on the demand for each mode of transport.

ICT is widely used to increase efficiency of transport through more efficient planning. This implies that more ton kilometers (and to a certain extent more person kilometers) can be realized per kilometer driven by a truck, sailed by a ship etcetera. This implies that more transport work can be carried out without increased impact on the environment. Finally ICT can be used for design of more environment friendly means of transport, e.g. less polluting cars and flights. This latter aspect is essentially dealing with design of more environmentally friendly processes of production and is not specifically related to the transport sector. This aspect will not be analyzed further in this section. Here the focus will be on the impact on the overall level of transport realized by each mode. This has also implications on how the impact on the environment is measured. The impact of transport on the environment is a multidimensional parameter including a large number of different environmental factors such as noise, emission of No_x and CO_2. However we will not address each of these parameters separately.

ICT penetrates all parts of our daily life and all parts of the production. It is therefore impossible to assess the environmental impact of every possible application of ICT, which affect our transport behavior. A study on the ICT impact must therefore concentrate on a limited number of parameters. ICTRANS – an EU project on Impacts of ICT on transport and mobility makes a distinction between ICT applications within three different socioeconomic domains (producing, living and working).

Within each of these domains the most important ICT applications with regard to impact on transport are identified (Table 1). Thus, some applications affect transport behavior within more than one socio-economic domain.

Table 1. Mapping application areas into socio-economic spheres [4]

Producing	Living	Working
Logistic Services		
Manufacturing Services		
Customized Services	Customized Services	
Retailing and distribution	Retailing and distribution	
	Teleshopping	Teleshopping
		Tele-working
		Distance Working
		Self-employment

We have chosen to limit our analysis to two different applications:

- Tele-work (including telecommuting, teleconferencing)
- Teleshopping

These applications are more broadly defined than those defined in the ICTRANS study and cover the most important aspects of the ICT impact on transport behavior within the three socio-economic spheres. As far as possible the analysis will include direct first order effects, as well as more indirect second and third order effects which will be presented. The base for this discussion will be a desk research. Furthermore a number of interviews are carried out with different actors in Denmark. The actors are presenting both the areas of research and the developing business.

2 Tele-work

There are many different definitions of tele-work, some definitions take the technology as point of departure and focus on how of ICT is applied in the work process, while others see tele-work as a new way to organize the work (which brings tele-work close to the concept of distance work). Sometimes tele-work includes only working from home and sometimes it includes any work related use of ICT. We will use a rather broad definition, which include all work related activities where ICT facilities are used to facilitate a change in location of work place. This definition of tele-work includes at least six different categories:

- Telecommuting (working from home and thereby avoiding person transport to and from the work place)
- Tele-working centers (working from a tele-center and thereby reducing person transport to and from the work place).
- Teleconferencing

- Mobile tele-working
- Self-employed tele-workers
- Offshore tele-working

In addition to these categories tele-medicine could be added as a separate category, but tele-medicine can also be seen as a special application of teleconferencing although it includes some applications, which are quite different from traditional conferencing. Also e-learning could be added as a separate category (examples of e-learning are provided in Table 2), as learning also may be a working activity. But in this context, it is more convenient to look at e-learning as a sub-category of some of the above categories. There is no reason to distinguish between e-learning from home and telecommuting and e-learning from the work place is, with regard to the impact on transport behavior, very similar to teleconferencing.

Telecommuting is the most classical concept for tele-work. Tele-work includes employees working from home using some sort of telecom facilities to communicate with their work place. Working from home is not a new concept but has taken place for centuries, but use of telecom facilities has made it a much more flexible solution, which can be used for more purposes. Tele-work 96 can be either part time or full time. Looking at statistics on diffusion of tele-work, it is important to take the definition of tele-work into account. It is common to define tele-workers as employees working at least one full day a week from home. But sometimes also employees working from home occasionally or only part of the day are included.

The concept of tele-working centers has in particular been used in US. Employees are allowed to do their work in a tele-working centre providing the similar facilities to those at the central office, but located in a shorter distance to the home of employees. The idea is to reduce commuting into the crowded city centers. Tele-working centers may be located in the suburbs, but tele-work centers have also been established in rural areas. Here the purpose is rather to foster regional development than to reduce transportation.

Teleconferencing includes on-line communication between two or more places of work. Most definitions of teleconferencing demand a video-link between the different locations. This application has so far not been very successful. The reasons for this have been that the technology has been expensive and inflexible. But this will change as broadband connections become more widespread, and it is possible to establish a video-link from the employees own computer. It can be argued that the use of a video-link is irrelevant for a discussion of the impact of transport behavior. But the idea is that a video-link enables types of communication that almost entirely can substitute traditional business meetings.

Mobile tele-workers are employees, which perform most of their duties outside their office. This could be sales people such as insurance agents or employees involved in repair and maintenance or after sale services. Such mobile workers use ICT to support their work and to reduce the need for visiting their work place once or twice a day. Self employed tele-workers are self employed, who maintain a part of their business contacts by use of one or more of the above mentioned concepts for tele-work. This makes it possible to serve customers far away, which in particular is of importance for self employed located in remote rural areas.

Table 2. Examples of e-learning [5], [11]

A master programme in ICT is offered in a co-operation between Aalborg University in Denmark and Ghana Telecom University Colleague in Ghana. The classroom teaching is limited to a few intensive seminars, while the remaining part of the teaching is mediated via the Internet. Even during the seminars e-learning is applied, as videoconferencing is used in most of the lectures. This enables students in Ghana to follow lectures conducted at Aalborg University. Even some of the oral examinations are conducted by use of videoconferencing facilities connecting the two universities. For the past fifteen years, the IEEE has met engineers' need for flexible and affordable materials through videos, CD-ROMs and self-study courses delivered to them by mail. The components of a typical IEEE Self-Study Course include a study guide, textbook, and final exam. These materials are structured to provide clear-cut learning objectives, self-testing opportunities and helpful information. It is expected that web-technology will be applied to provide this type of training in the future [6] provides an on-line example of such a course.

Finally off-shore tele-working should be mentioned, although the direct impact on transport behavior might seem to be less clear cut than for the other categories. Off-shore tele-working includes out-sourcing of certain information intensive service functions to other areas. This could be routine jobs like ticketing and customer handling from call centers, but also more specialized consultancy services may be out-sourced [1]. The relation to tele-work is that these types of out-sourcing necessitate intensive use of ICT for exchange of information and to become economically viable.

The direct impact of tele-work on transport behavior is in both the living and the working spheres. 1) Telecommuting and 2) tele-working centers relate to the living sphere only, while 3) teleconferencing and 6) off-shore tele-work relate only to the working sphere. 4) Mobile tele-working and 5) self-employed tele-workers relate to the transport behavior in both spheres.

2.1 Diffusion of Tele-work

Estimations on the diffusion of tele-work vary considerable depending on the source. Although it must be expected that the numbers of tele-workers are growing, some of the most optimistic estimations dates back to the early 80's. At that time it was foreseen that as much as about 50% of all office workers would be teleworking.[4] The most recent estimates are much more modest as they shows that 13% of the work force in EU15 was engaged in some sort of tele-work in 2002 (compared to only 6% 1999). Out of these 7.4% are home based. The potential seems however to be considerable larger as two thirds are interested in either occasionally or permanent to work from home according to an ECATT survey from 1999 [7]. In the 90s tele-workers were mainly belonging to the higher echelons of the labor market, but following substantial reductions in prices for establishing tele-working facilities more groups are using this opportunity.

Table 3. Types of tele-work (in %). Incidence of tele-work in selected countries and the EU27, 2005 (%) [10]

Countries	% involved in tele-work at least 'a quarter of the time' or more	% involved in tele-work 'almost all of the time'
Czech Republic (CZ)	15.2	9.0
Denmark (DK)	14.4	2.6
Belgium (BE)	13.0	2.2
Latvia (LV)	12.2	1.8
Netherlands (NL)	12.0	1.9
Estonia (EE)	11.8	1.4
Finland (FI)	10.6	1.6
Poland (PL)	10.3	2.3
Norway (NO)	9.7	1.3
Sweden (SE)	9.4	0.4
United Kingdom (UK)	8.1	2.5
Germany (DE)	6.7	1.2
France (FR)	5.7	1.6
EU27	7.0	1.7

It follows from Table 3 the figures for tele-working varies significantly between the countries. It should be noted that tele-working reduces commuting only, when tele-workers work from home full working days. A survey conducted by Danish Technological Institute indicates that there are very few tele-workers working a full working day from home in Denmark [12]. In Denmark a tax incentive for companies investing in home-based PCs to the employees have had a significant impact on the number of tele-workers. The multimedia tax, introduced in 2010, has removed this incentive, so employees must pay 450 Euro per year, if they are provided with any employer paid ICT devices – even if they are used for work related activities only. This has reduced the number of tele-workers dramatically. In Denmark tele-work is usually considered as a basic labor right, while introduction of tele-work in most other European countries is introduced only if it can be justified in financial terms [13], this makes it difficult to make exact estimates on the number of people using tele-work on a regular basis.

2.2 Impact on Transport Behavior in the Sphere of Living

The factors affecting transport behavior can be summarized as within Table 4. Substantial efforts have been made to quantify the transport impact. In particular the substitution effect has been calculated in a large number of studies. Most studies foresee a reduction between 1-3%. According to Mokhtarian, many of the studies tend however to overestimate the impact as they do not include second order and third order effects. She estimates the effect to be less than 1% of the total travel miles [9]. A Danish study from 1996 estimates the potential impact in Denmark to be 0.7% [14].

This figure is confirmed by a more recent unpublished study by Danish Technological Institute (Danish Technological Institute). However, if home working (working from home without use of ICT facilities is included) a much higher impact can be obtained.

Table 4. Environmental impact of tele-work on transport behavior in the sphere of living

First order effects:	Substitution: The level depends on the number of telecommuters, the frequency of telecommuting and the distance between home and work place (or tele-center) Urban sprawl: Reduction in rush hour traffic
Second order effects:	Short term: Impact on non work related transport Impact on transport behavior for other members of the household. Long term: Reduction in number of private cars Changes in habitation More flexible labor market
Third order effects:	Development of public transport Localization of work places Regional development

The short term second order effects (also called the rebound effect) have been included in a study made as part of the EU funded SUSTEL project. This study indicate that a substantial part of the transport savings are nullified by increased transport for other purposes such as shopping and increased transport by other family members. The latter is particular relevant in one car families.

Table 5. Commuting reductions and rebound effect [13][1]

	Denmark	Germany	Italy	Netherlands	UK1	UK2
Reduction in weekly commuting (km)	105	283	242	98	253	61
Addition travel (km)	77	53	33	42	60	15
Rebound effect in %	73	19	14	43	24	25

2.3 Impact on Rush Hour Traffic and Modality

Commuting is characterized by its regularity: It goes to the same destinations at the same time every day. Commuting is the major source for urban sprawl in the rush hours. Increasing use of tele-work from home will provide more flexibility to the

[1] Two case studies were carried out in UK.

commuters so they will be in a better position to avoid rush hours. Tele-work will therefore imply a more equal distribution of the load of person traffic during the day. This will lower problems related to crush during rush hours, but may also add to more traffic in person cars, as this may be the preferred mode of transport outside rush hours. Tele-work may imply that people will accept to travel longer distances or on routes not covered by public transport services once they need to visit their work place. Both will add to less use of public transport services. This is illustrated by the fact that public transport has a market share above average in commuting related transport purposes.

2.4 Impact on Transport Behavior in the Sphere of Working

The factors affecting transport behavior can be summarized as in Table 6. The impact of transport behavior in the working sphere is much less studied than the impact in the private sphere. One reason maybe that with regard to personal transport commuting is seen as the major transport problem - not so much because of its dominant role in the total transport – but rather because it is the major cause to urban sprawl during rush hours. Another reason is that it is much more straightforward to calculate the substitution impact with regard to telecommuting. Business trips are not as regular as commuting trips and will often be longer than commuting trips. It is very difficult to estimate the potential for substitution. In particular if this potential is defined as additional substitution compared to what is done today.

Communication between businesses takes many forms including use of low tech solutions such as letters and phone calls, and a video conference may be a substitute for these types of communications as well as for a business trip. The above mentioned study from Arthur D. Little, is one of the few attempts to estimate the substitution effect. Here it is assumed that 13-23% of all business trips may be substituted. This includes transport related to learning activities.

Table 6. Environmental impact of tele-work ontransport behavior in the sphere of working

First order effects:	The level depends on the number business it is possible to substitute and length of the trips.
Second order effects:	More intensive communication with current business partners. Extension of business networks More outsourcing and specialization
Third order effects:	Out-sourcing and globalization of production. Internationalization of markets Localization of work places Regional development

One example is air maintenance. In this case most of the necessary information is stored in a digitized format, and maintenance and repair decisions can therefore be taken without physical presence of aviation experts. In the same way it may possible to operate robots used for medical operations. E-learning can be implemented by use of e-mail only, but distant conduction of lectures and oral examinations demand more sophisticated ICT applications. The transport implications of mobile tele-working are

rather different than those for home based tele-working. Like home based tele-workers mobile tele-workers may avoid commuting to their work place, but they may increase transportation during working hours. A study by BT in which most tele-workers were mobile tele-workers indicates that the total transport work may increase. 18% of the respondents stated that there in work travel increased by an average of 267 miles per week, while 9% stated that it decreased by 394 miles.

2.5 Long Term Perspectives

Tele-work does not require use of advanced ICT technologies, but new technologies may open-up for new applications of tele-work. In the short term mobile technologies will be the most important. 3G will enable more mobile applications of data transfer and video, making it easier to connect not only from home but also from any other location. Security will also be a crucial parameter, as companies still may be hesitant to enable access to sensitive information from outside. In the long term development of high quality video communications offering virtual reality like alternatives to physical presence may be developed to facilitate informal knowledge sharing.

The long term impact will however also depend on how conditions for personal transport evolve. Development of alternatives to physical presence will depend on how difficult it will be to make use of physical presence. If transport is both expensive and time consuming electronic alternatives are more likely to be developed.

3 Teleshopping

The concept of teleshopping covers a wide range of business activities with very different implications for transport and the environment. We will in our discussion focus on three different activities:

- Before sales: Activities related to identification of providers or customers and services/products to be acquired.
- Sales: Processes related to the sales transaction such as payments, delivery, signing of contracts.
- After sales: amongst others customer support and maintenance.

Teleshopping and to a certain extent e-business tend to focus on the sales process itself, but after sales and in particular before sales are equally important functions – also with regard to transport implications. E-business affects both the working and the living spheres. B2B will mainly affect the working sphere, while B2C affects both living and working.

E-business in relation to consumers is in reality the same as teleshopping. Teleshopping is not an entirely new concept. Similar ways of distant shopping has been carried out without use of advanced ICT. Mail order has been used for decades and ordering by phone is also a well-established way of shopping. However, the Internet and a wider penetration of broadband, has enabled a dramatic increase in the potential for distant shopping. The benefits of teleshopping for consumers are:

- More convenient shopping
- Timesaving
- Savings in transport
- Faster delivery
- More transparent markets
- Better market access
- Periphery regions/developing countries
- Physical impaired
- More competition

Table 7. List of impacts on transport behavior from B2C (Adapted from [15])

• Some shopping trips will be replaced by deliveries. • B2C will result in the increase of small-part sending (e.g. courier, express and packet deliveries) to an increased number of end-customers with individual delivery-places and delivery-times • The total number of tours will increase. • B2C-traffic will concentrate on suburban areas. • Storage concepts, distribution and collecting traffic have to be adapted. • Small part sending will require more small vehicles.

More transparent markets are in particular related to before sales processes, where different products and suppliers are compared. This can be done much faster and without any person transport. This may however imply that the consumer become aware of suppliers located long away. If the actual purchase is done in the traditional way, the transport savings achieved through electronic scanning of the market, may therefore be nullified through more transport in the sales process. One of the major barriers towards teleshopping has been establishment of efficient distribution systems. Teleshopping has therefore been particular successful in areas, where the goods either can be transmitted via the telecom network or where they can be delivered via the existing postal mail systems. A study by the German ministry of for Transport lists following effects of teleshopping on traffic (Table 8). The list is made through a survey of a large number of German studies. The list implies that B2C is foreseen to have a wide range of impacts on transportation, both on the overall levels of freight and person transportation, and on the structure of the transport. It is however difficult to derive any firm conclusions on whether transport will increase or be reduced, in particular if second order and third order effects are included.

B2C will increase transport related to delivery of goods and change the structure towards smaller units, but this does not necessarily increase the total needs for transport. According to an American study, best-selling books ecommerce has had a smaller impact on the environment than traditional delivery. Also a Swedish study indicates that e-commerce not necessarily will lead to more traffic. In the long term a wide penetration of tele-shopping may add to the on-going centralization of the retail market, which may imply that both shopping trips and e-shop deliveries will involve longer transport distances.

Table 8. Environmental impact of e-business on transport behavior in the sphere of living

First order effects:	Substitution of transport related to market scanning. Substitution of transport with intangible goods. Substitution of person transport with delivery of goods. Change in freight transport towards smaller units.
Second order effects:	Centralization of shopping facilities Some services only available on-line
Third order effects:	Out-sourcing and globalization of production. Internationalization of markets Localization of work places Regional development

3.1 Quantitative Impact of Teleshopping

The potential transport savings depends of the share of personal transport, which is related to shopping. According to the latest survey of transport behavior in Denmark [3] 22% of person transport is related to shopping. It should however be noted that shopping is often combined with other activities (combined trips). This implies that savings will be smaller than that, even with a 100% substitution. The key in transport savings will be if teleshopping is used for daily necessities, and not only for books, durable consumer goods and other kinds of goods bought with low frequency. So far teleshopping in this area has remained limited in spite of the convenience potential savings in both transport and time.

An estimate of the potential impact of teleshopping in Denmark is as low as 0.3% of the total personal transport [14]. Although the figure is somewhat dated and that the potential may have increased since then (for instance due to a centralization of the shopping structure), it gives an indication of how limited the potential is.

4 Conclusions

This section has analyzed the impact of two ICT applications on the total demand for transport (tele-work and teleshopping). These applications were selected as they were expected to be among the applications with the highest potential for savings in transport. In spite of this it is concluded that the total impact is limited and might be even negative if rebound effects are included in the analysis. Still the application of ICT may be able to offer new possibilities for reducing the negative impact of transport on the environment. ICT is only one out of several parameters affecting transport behavior. A major problem in this context is that ICT both offers possibilities for substitution of certain types of transport, and contributes to ongoing behavioral trends at the individual and societal levels that lead to increases in the overall demand for transport. If the use of ICT is accommodated by other measures aiming at reduced demand for transport, such as heavy taxation, ICT can be used to facilitate a development towards less transport intensive lifestyles.

References

1. Baark, E., Falch, M., Henten, A., Skouby, K.E.: The tradability of consulting services. UNCTAD, New York and Geneva (2002)
2. Boghani, B.A.: Can telecommunications help America's transportation problems? – A multiclient study. Cambridge Massachusetts: A.D. Little (1991)
3. Danish Bureau of Statistics, Transport 2005. Copenhagen Denmark: Danish Bureau of Statistics (2005)
4. ESTO, Impacts of ICTs on transport and mobility (ICTRANS). Seville: The ESTO Research Report (2003)
5. Falch, M., Tadayoni, R.: Practical experiences with using E-learning methodologies at CICT. In: Digital Learning India 2006 Conference, New Delhi, August 23-25 (2006)
6. Havyatt, S.: Impacts of teleworking under the NBN. Canberra, Australia: Access Economics (2010)
7. Hommels, A., Kemp, R., Peters, P., Dunnewijk, T.: State of the art Review—Living. Paper prepared for the ESTO study on the impacts of ICT on transport and mobility. Seville: ESTO (2002)
8. Korte, W., Robinson, S., Steinle, W.: Telework: Present situations and future development of a new form of work organization. North-Holland, Amsterdam (1988)
9. Mokhtarian, P.L., Choo, S., Salomon, I.: Does telecommuting reduce vehicle-miles travelled? An aggregate time series analysis for the US institute of transportation studiesUniversity of California (2002)
10. Parent-Thirion, A., Macías, E.F., Hurley, J., Vermeylen, G.: Fourth european working conditions survey. European Foundation for the Improvement of Living and Working Conditions (2010)
11. Ranky, P.: Introduction to sustainable green engineering, `http://ieee-elearning.org/` (retrieved November 10, 2010)
12. Schmidt, L.B.: The impact of eWork on families and the social consequences. Aarhus, Denmark: Danish Technological Institute (2005)
13. SusTel: Is teleworking sustainable? An analysis of its economic, environmental and social impacts. European Communities (2004)
14. Transportrådet. Distancearbejde og teleindkøb – konsekvenser for transporten distance work and teleshopping - impact on transport behaviour, No. 96.09. Copenhagen: The Danish Transport Council (1996)
15. Zoche, P., B., B., Joisten, M.: Impacts of ICTs on transport and mobility (ICTRANS) annex: The impact of ICT on mobility and transport in the socio-economic sphere of working. In: FhG-ISI (2002)