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How worthwhile is teleworking from a sustainable mobility perspective? The case of Brussels Capital region.

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Since the 1960s, the number of commuters in the Brussels Capital Region has doubled: nowadays more than 400,000 workers commute in and out of Brussels on a daily basis. In order to preserve the liveability of the region in terms of mobility, environment and traffic safety, policy measures should be taken to reduce the number and/or distances of commuter trips. Telework is often suggested as an instrument to reduce the environmental and socio-economic impacts of mobility on society. Currently, the implementation of teleworking is however still rather limited and fragmental in most companies in Belgium. Goal of this paper is to assess whether further encouragement of telework is advisable from a sustainable mobility viewpoint. Based on Belgian survey data, an appraisal of the environmental and mobility related impacts of telework for companies located in the Brussels Capital Region is performed, using an analysis of the strengths, weaknesses, opportunities and threats of telework. In order to quantify the effects, external costs of trips to the central headquarter office are compared to those of trips to decentralized satellite offices and those caused by additional distances travelled when teleworking at home. Modal shifts occurring between trips travelled to the central office and trips travelled to the satellite office are taken into account and play an important role in the overall impact on external transport costs. Also receptor density and congestion levels along the routes travelled are taken into account.

Keywords: *External costs, sustainable mobility, telework.*

1. Introduction

In the Brussels Capital Region (BCR), the number of commuters has doubled since the 1960s (Brussels Observatory for Employment, 2009). A labour market survey conducted end 2010 estimated the daily number of jobs in BCR to be 714,110 (Lebrun et al., 2012). BCR is not only a region with a substantial increase in new job employment (8.4% increase between end 2000 and end 2010 (Federal Government Agency for Economy, 2010)), on a yearly basis the number of workers coming from the Flemish and Walloon Region to work in BCR is rising as well. End 2010, some 371,700 Flemish and Walloon commuters were estimated to work in Brussels, so more than half of the jobs in BCR were filled by workers not living in BCR (Lebrun et al., 2012). In addition, there is also an increase in the opposite direction: between 2004 en 2010, the number of people from Brussels commuting to jobs in the Flemish and Walloon region increased with 27% to 61,140 (Federal Government Agency for Economy, 2010). On an average day, the car remains the principal transport mode for trips to and from BCR (more than 60% in 2010 according to Lebrun et al. (2013)), hence the road network in and around BCR is increasingly congested and

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confronted with additional externalities such as pollution, climate change, noise and road safety hazards. Measures are therefore required to reduce the number of trips and/or travel distances, in order to safeguard the quality of life in the Brussels region in terms of mobility, environment and road safety (Castaigne et al., 2009).

One possible measure to tackle the mobility challenge is to encourage telework. Telework, the time and place independent work by using information and communication technologies (ICT's), can potentially reduce the home-work trips and the associated mobility effects significantly (if the employee can commute to a nearby satellite office) and possibly even avoid them completely (if the employee can work at home) (Vanoutrive et al., 2010, Nilles, 1988; Illegems and Verbeke, 2003; Dooms et al., 2006; Horvath, 2010). Moreover, under certain conditions, potential environmental benefits can exist in terms of energy consumption (heating, lighting and the use of electrical appliances) in the headquarter office (HQ) when employees work from home and/or work in a satellite office. On the other hand, telework might also cause an increase of the energy consumption at home and in the satellite office, and initiate additional non-work related trips during the day. Hence, telework can potentially create additional costs to society in terms of mobility and environment.

Even though teleworking is becoming economically more attractive through the evolution in ICT, it is at present not yet a widespread measure in large companies (> 200 employees) in BCR. Analysis of company transport plans by the Brussels Environmental Agency showed that only 36% of large companies in BCR formally implement telework (Leefmilieu Brussel, 2010). Nevertheless, telework is gaining importance during the last years, illustrated by an increase of 11% between phase 1 (25%) and phase 2 (36%) of the number of companies that included teleworking in their company transport plan (Leefmilieu Brussel, 2010).

From a policy viewpoint, the magnitude of the impact of teleworking on environment, mobility and socio-economic aspects is therefore relevant in order to determine whether a further encouragement of telework is useful and sustainable for society as a whole. Based on the combined results of a literature study, a survey of employees and employers in six large companies based in BCR and a discussion with the mobility managers of these companies, an analysis of strengths, weaknesses, opportunities and threats (SWOT) of telework in terms of mobility, environmental, social and economic aspects in BCR was carried out. In this paper, focus is on aspects related to mobility and environment. Specific attention will be given to the quantification of mobility effects of teleworking on society. To this end, detailed external cost calculations of commuting trips to the central office will be compared to those of commuting trips to satellite offices and those caused by additional distances travelled when teleworking at home.

The next section (section 2) starts with a literature study explaining the general concept of telework and summarizing the major findings in scientific literature with regards to telework. In section 3, the research methodology is described. Section 4 discusses the results of the SWOT analysis, focussing on the strengths, weaknesses, opportunities and threats of telework with regards to mobility and environment. Section 5 focuses on the quantification of mobility effects of teleworking from a sustainability perspective by calculating the external transport costs of different scenarios. Finally, section 6 formulates conclusions and recommendations.

2. The concept of telework

2.1 Definition of telework

As mentioned by Baruch (2001), scientific literature in the 1950s on the evolution in information and communication technologies (ICTs) already led to the idea that "*telecommunications combined with computing technology could enable work to be relocated away from the traditional office*". The term teleworking originated in the 1970s to denote remote working away from the office headquarter location (HQ), often at flexible times. Academic and managerial interest gradually rose in the following decades. Although forms of remote work are already in use for decades, the enormous potential for variation amongst teleworkers in terms of their contractual arrangements, employment status, type of work and work location has impeded a universally accepted definition of telework suitable for academic research (Baruch and Smith, 2002; Sullivan, 2003; Wilks and Billsberry, 2007; Taskin and Walrave, 2010). In the US, the term 'telecommuting', which stems from early conceptualizations of telework that tended to focus on its potential to avoid or even eliminate commuting, is commonly used. But according to Sullivan (2003) this terminology confuses the issue of defining and conceptualizing telework by overemphasizing transportation. So other terms emerged over the years such as 'home working', 'working-at-a-distance', 'off-site working' or 'remote working', which may all have similar meanings and are used interchangeably (Baruch, 2001). Wilks and Billsberry (2007) suggested to use the term 'home anchored working' as opposed to 'office-anchored working'. Regardless of the differences between the names and related definitions used, following elements are generally considered essential: the location dimension (with emphasis on the remoteness), the time dimension and the use of ICT (Denolf et al., 2006).

Various sub-types of telework can be distinguished based on the location of telework (Baruch, 2001, Walraeve and Dens, 2003; Illegems and Verbeke, 2003). Telework can be performed on as well as off company premises. On company premises, the most common form is working in so-called satellite offices or telecottages (the latter being locations shared with other companies). An important aspect of these decentralized offices is that their location usually has better accessibility for employees than the company headquarters (Helling and Mokhtarian, 2001; Walrave and De Bie, 2005)[4]. A second, more popular form of telework is working at home, and thus off company premises. In addition, a third category of teleworker exists: the mobile or nomadic teleworker who works while travelling (on the airplane, at costumer locations, in hotels) (Walrave and De Bie, 2005). This form is often used by consultants or travelling salesmen. In this paper, focus will be on telework at home and at the satellite office.

Despite the potential and predicted popularity of telework (i.e. Olson and Primps, 1984; Köhler, 1987), the implementation so far has been rather limited compared to what was forecasted (i.e. Baruch, 2000; Glorieux et al., 2006). According to Pyöriä (2011), the slow spread of telework is partly due to a lack of or a too restrictive legal framework and a lack of an overall telework culture.[5] Hence, the expected telework boom still has to emerge, driven by ever increasing commuting times and further development of ICT applications. Over the last decades, the academic interest in the different aspects of various forms of telework has continued to grow and a substantial amount of scientific literature on the topic already exists. Although in the context of this research, focus is mainly on impacts of telework on mobility and environment, a short overview of the major findings regarding telework in scientific literature is given below in order to delineate the broader context.

2.2 Literature on impact of telework on mobility and environment

Initially, most teleworking related research focused on the travel reduction potential of teleworking and thus on mobility related aspects. Teleworking was seen as a solution to problems of traffic congestion and pollution by decreasing the number of commuter trips (Baines, 2002; Pyöriä, 2003). Also other studies claim that telework has a significant influence on the sustainability of mobility (e.g. Nilles, 1988; Illegems andVerbeke, 2003; Dooms et al., 2006; Ktou and Horvath, 2008; Horvath, 2010). Walls and Safirova (2004) reviewed the empirical literature

[4] Sometimes satellite offices are however also used as a term for flexible offices in the company headquarters where workers that have their location elsewhere are given the opportunity to work part of their time at the company headquarters. In this paper, we only focus on decentralized satellite offices on other locations away from the company headquarters.

[5] Baruch and Smith (2002) discuss the legal aspects of teleworking and the related implications for both the management of organisations and the legal establishment.

on telecommuting from the trip reduction perspective and provide an overview of US studies that try to quantify the potential of telework to reduce vehicle trips, miles travelled, and emissions of various pollutants. Findings in these studies show that on average vehicle miles travelled by an employee are 53% to 77% lower on telecommuting days than on non-telecommuting days, significantly reducing levels of organic gases, NO_x, CO, and particulate matter. Optimistic figures on the travel reduction potential of teleworking are however put in perspective by Fuchs (2008), who states that "*looking from a macro perspective at passenger transport does not reveal a significant influence from home-based telework on the number of commuting trips nor the commuting distances travelled*".

This links the discussion regarding the trip reduction potential of telework to the broader literature on constant travel time budgets. This concept refers to the idea that average daily travel time of individuals tends to be relatively constant. The behavioral hypothesis behind this concept is the idea that people are spending a certain amount of time on travel and will make adjustments to minimize departures from that budget in either direction (Tanner, 1981). This constancy of travel time would imply that the development of faster transport modes leads to longer travel distances. It would also imply that the decrease in travel time by eliminating commuter trips through teleworking would be compensated by increasing travel time spent on other trips, seriously limiting the potential of telework to improve mobility. However, based on findings from more than two dozen aggregate and disaggregate studies of travel time (and sometimes money) expenditures, Mokhtarian and Chen (2004) concluded that travel time expenditures are not constant except possibly at the most aggregate level. At least in the short run, individuals that telework more are assumed to travel less, at least during peak hours, although De Graaff (2004) states that this relationship is not convincingly supported by empirical data as well. Van Wee et al. (2002) even note that over time individuals usually tend on aggregate to travel more per day than less, but in their opinion this possible increase in travel time is mainly caused by the increased utility of trips in general and of longer trips in particular in terms of travel time, as well as by changes in the transport system.

In teleworking literature, the trip reduction potential due to teleworking is therefore still believed to exist and regarded as the most important factor in determining the environmental impact of teleworking (Nilles, 1988; Mokhtarrian et al., 1995; Mokhtarian, 1998; Dooms et al., 2006; Kitou and Horvath, 2008; Horvath, 2010). This environmental impact is however also influenced by reductions and increases in energy consumption in company headquarters, satellite offices and at home as a consequence of changes in heating/cooling and lighting of work spaces and increased or decreased use of electric appliances (Kitou and Horvath, 2002). Less research has been performed on this broader energy consumption impact of teleworking. Mokhtarian et al. (1995) did investigate the extra energy consumption at home when teleworking and concluded that the effects were negligible compared to the environmental impact of travel reduction, but they did not incorporate the energy consumption impacts in the offices. Matthews and Williams (2005) studied the effects of teleworking on the energy consumption in offices in the United States and Japan and estimated, based on scenarios, an energy reduction in offices of 0.01% à 0.03%. In their opinion, this could increase to 1% if the penetration degree of teleworking would reach 50% and if teleworkers would work at home four days out of five. However, the second condition in particular seems rather unrealistic to achieve in practice.

Kitou and Horvath (2008) apply a systems model to telework and non-telework scenarios to quantify direct energy and fuel costs and external costs related to air emissions from transportation, heating, cooling, lighting, and electronic and electrical equipment used both at the company and the home office.[6] They find that five-day telework scenarios on cooling days in California can have about 50–70% lower total costs when compared to not teleworking. The authors stress that important parameters such as telecommuting frequency, characteristics of the

[6] The concept of external costs is explained in section 5.1

office and home space, climate patterns, and rebound effects that determine external costs along with the price of gasoline, electricity and natural gas can greatly influence the final results of telework programs.

Fuhr and Pociask (2011) made a very rough estimate of the environmental benefits of telecommuting for the next 10 years with focus on energy, greenhouse gas and air pollution reduction. They distinguish between direct effects from driving, indirect effects from congestion, effects from office space not built and effects from saved office space energy, to arrive at an incremental cumulative benefit of almost 600 million tons of greenhouse gasses over the next ten years. A more detailed analysis of the impact of telework including other categories of external costs such as noise and accidents is however currently lacking in literature.

2.3 Literature on other aspects of telework

Due to its nature, teleworking is clearly not possible for all companies or for all employers within a company. The sector in which a company operates is therefore an important factor for the feasibility of implementing telework (Illegems and Verbeke, 2003). Walrave and De Bie (2005) identify service companies, financial institutions and ICT companies as examples of sectors with a high penetration degree of teleworking, where about 60% to 80% of employees have the potential to telework. In sectors where the physical presence of (a large part of) employees is required, such as construction, catering, health services, transport and logistics, will obviously have a lower penetration rate. In practice it will often be the direct supervisor who will decide whether an employee can/may telework, based on the job content since not all jobs can be performed at home or in a satellite office (Dambrin, 2004). Although teleworking is assumed to be more prevalent in large companies since they are more likely to be responsive to work-family issues than small ones, research by Mayo et al. (2009) suggests that teleworking is more commonly found in smaller firms (with less bureaucracy, less inertia and a more dynamic entrepreneurial culture).

In order to assess the potential of teleworking it is crucial to understand the possible benefits and drawbacks of teleworking for employees and employers. Baruch (2000) identified the possible benefits and shortcomings of teleworking on an individual, organizational and national level. Possible benefits for employees mentioned are i.e. better productivity, less commuting time, less work related stress, a better work life balance. Important possible shortcomings for employees are i.e. fewer opportunities for affiliation, social isolation, more home related stress, less influence over people and events at workplace. From an organizational perspective, possible benefits are i.e. higher productivity, space saved, lower overhead costs, less absenteeism, and possible shortcomings are i.e. loss of control, less committed employees and loss of teamworking benefits. On a national level, benefits identified are less commuting, less pollution, less congestion and less accidents and the fact that more people can work (e.g. disabled people). Possible shortcoming on the national level is the creation of an autistic society. Raiborn and Butler (2009) also provide a similar overview, with some added benefits and drawbacks for employees such as a virtual raise, potential workaholism and space/noise management issues, and potential difficulties with data security and morale issues among non-teleworking employees as additional drawbacks for employers. The benefits and drawbacks can however vary from company to company depending on goals and context of the company (Denolf et al., 2006).

From an employer's perspective, loss of supervision is clearly identified in literature as one of the major obstacles to implement teleworking (Di Martino and Wirth, 1990; Illegems and Verbeke, 2004, Dambrin, 2004). Kowalski and Swanson (2005) identify trust between managers and employees at all levels of the teleworking organization as "*probably the most critical factor for success in teleworking*" next to the other critical success factors "support" and "communication".

An improved work-life balance is often cited as a major employee benefit of telework, extensive research of this impact is not conclusive and shows that this is not always the case (Baruch, 2000; Wilks and Billsberry, 2007; Hilbrecht et al., 2008; Raiborn and Butler, 2009). Crosbie and Moore

(2004) therefore stress the need for carefully addressing work-life balance issues when implementing telework programs. On the part of employees, social isolation is a major potential drawbacks of teleworking (Haddon and Lewis, 1994; Baruch, 2000; Wilks and Billsberry, 2007), that may also negatively influence teleworker job performance and turnover intentions (Golden, Veiga and Dino, 2008). Mann and Holdsworth (2003) even state that "*teleworking has a significant emotional impact on employees as reports of negative emotions such as loneliness, irritation, worry and guilt were more apparent than with office-workers*". In their opinion this supports the proposition that although the implementation of teleworking may reduce organisational costs, the quality of working life may not necessarily be improved. Kamerade and Burchell (2004) on the other hand contradict claims that teleworking can lead to a society of isolated individuals since their European study reveals that teleworking seems to be a community-friendly form of work that facilitates people's engagement in the life of the community. The casual direction for this positive relationship between teleworking and participatory capital (defined as involvement in voluntary and political organizations) is however not clear.

3. Research methodology

The methodological basis for our analysis of the impact of telework in large companies in BCR with respect to ecological, socio-economic and mobility related aspects is a combination of a literature review, a survey of six large companies in BCR[7] and a discussion with the mobility managers of these six companies. The literature review provided an insight into the concept of telework and the important determinants, and served as the basis for drafting the questionnaires. In order to collect the necessary data to analyse the impacts of telework, two questionnaires were developed. On one hand a paper questionnaire for the mobility manager and/or manager responsible for telework in each company and on the other hand an online questionnaire for employees.

The questionnaire for the employers contained questions with regards to the size of the company, the number of teleworkers (if applicable), the departments where teleworking was allowed, the motives for employers to introduce teleworking and the organization of telework (frequency, functions, tasks, employee availability, personal criteria, use of flexible hours, parking policy in the company). A specific part of the survey was dedicated to the impact of telework on energy consumption (heating, lighting, electronic appliances) in the office locations (headquarters and satellite office). Another part focused on the economic impact of teleworking on the company office locations (number of electronic appliances needed, change in required office space and furniture, change in ICT costs, etc). To finish, the opinion of the employers was asked regarding statements on teleworking.

The online questionnaire for the employees started with questions on socio-demographic aspects (age, gender, postal code, marital status, education, etc.) and professional characteristics (worker profile, functions, labour organization). A very large part of the survey was devoted to the travel behaviour of the employees in order to understand how they commuted to headquarters and satellite offices (if applicable), and which trips were conducted when working at home (if applicable). Telework frequency, travel time, travel distance, trip timing, detour aspects going to and from work, modal choice, type of vehicle, parking aspects, vehicle characteristics, perceived congestion when travelling, use of flexible hours (if applicable) and modal shifts occurring when teleworking (e.g. travelling by car to headquarters but by car to satellite office) were all investigated. Particular attention was given in order to identify additional vehicle kilometres when working at home. Another part of the survey focused on the employee motives and barriers for teleworking (also with non-teleworkers). Also the type of tasks performed when

[7] The number of companies to be investigated was predetermined by the commissioner of the study, the Brussels Institute for Administering the Environment (IBGE/BIM).

teleworking were questioned. The survey used mainly a combination of predefined choices and the possibility to provide a specific answer for the questions asked, allowing respondents to answer as accurately as possible.

The surveys were conducted in six large companies (having more than 100 employees), with a Belgian headquarter office located in BCR, where (part of) the employees are formally or informally allowed to telework, and where a mobility manager is active. The selection of these six companies was based on a multistage random sample drawn from the database on company mobility plans[8] provided by the Brussels Institute for administering the Environment (IBGE/BIM). In total, this database contains 272 companies, of which 80 are involved in teleworking. 34 of these 80 companies also had a mobility coordinator and thus met the criteria imposed.

Given the importance of accessibility to the workplace as a determinant of commuting behaviour of an employee (Van Acker et al., 2007; Verhetsel et al., 2007; De Witte et al., 2011) the selection of the companies took also into account different accessibility zones by means of public transport. Distinction was made between zones with very good access, which are the neighbourhoods near the three main railway stations on the north-south axis and major nodes of the STIB[9] (Arts-Loi, Rogier and De Brouckère). At the second level, zones with good accessibility are identified. These are neighbourhoods located around the metro and pre-metro network, supported by a public transport offer with a relative high frequency. The third level of accessibility by public transport concerns the rest of the region, accessible by tram and bus (Leefmilieu Brussel, 2010).

The six companies, pairwise located in the same accessibility zones, were each selected from a different sector: chemicals, telecommunications, banking and insurance, consulting, welfare and media, and the audio-visual sector. Three selected companies implemented both forms of telework (teleworking from home and at the satellite office), two companies formally allowed telework from home while the last one merely facilitated telework in a satellite office. In each company, both non-teleworkers and different types of teleworkers received the questionnaires. This multistage random sampling methodology allowed identifying and comparing a number of homogenous subclasses (De Pelsmacker and Van Kenhove, 2006).

The survey research was conducted between April 2011 and July 2011. Based on De Pelsmacker and Van Kenhove (2006), a response rate of around 30% was expected for this type of research. A minimum of 30 valid questionnaires per category of worker and per company was considered necessary for analysis, hence companies were asked to distribute questionnaires to at least 200 employees. Instead of the hoped and expected 540 employees, a higher total of 1,247 employees provided correctly completed questionnaires. Analysis showed that more than half (52%) of them regularly telework (Figure 1). Within the group of teleworkers, 16% telework at the satellite office, 32% regularly telework at home and 4% combine both telework forms. The remaining 48% of respondents are non-teleworkers.

In addition, the mobility managers of the companies were invited to a round-table meeting that took place on September 13, 2011, where the results of the survey were presented and discussed. Afterwards, all the information resulting from the literature research, the survey and the round-table meeting were brought together in a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis. The data and information gathered was also used to conduct a detailed analysis of the impact of telework on the most important categories of transport externalities such

[8] A company mobility plan consists of the study, the implementation and monitoring of actions of one or more companies to manage trips related to the company activity in a more sustainable way. The establishment of such a company mobility plan is compulsory for all public or private companies that employ more than 100 employees on a same site in the Brussels Capital Region.

[9] STIB (Société des Transports Intercommunaux de Bruxelles) is the Brussels urban public transport company, which serves the 19 municipalities of the Brussels Capital Region as well as 11 other outlying municipalities. The STIB network has 4 metro lines, 18 tram lines, 50 bus lines and 11 night bus lines.

as climate change, air pollution, noise, accidents and congestion. Since such a detailed analysis of the impact of teleworking from a societal point of view was currently lacking in literature, the main academic contribution in this paper is therefore to be found in section 5.

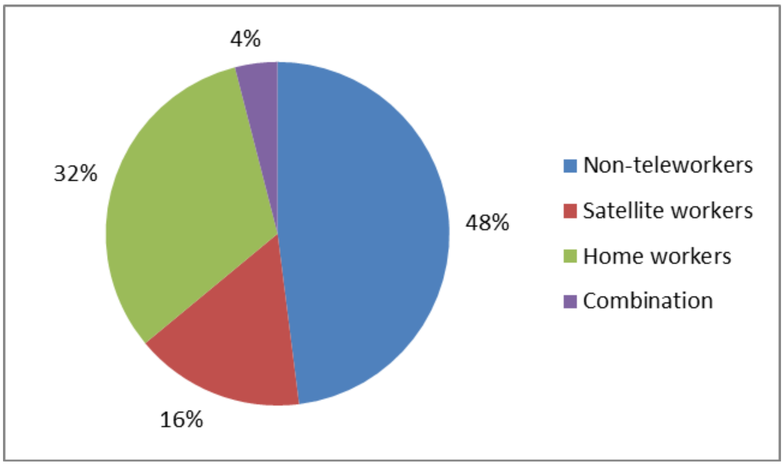


Figure 1. Distribution of respondents by type of telework (n=1247) (MOBI, 2012)

4. SWOT analysis

A SWOT analysis is a decision support tool that lists the strengths and weaknesses of a measure or project (in this case telework), along with the related opportunities and threats (Pahl and Richter, 2007). For identifying the strengths and weaknesses, the characteristics and effects of telework were analysed. For the opportunities and threats, a broader vision was used, focusing on the developments, events and influences of the impact of telework. Taking these four aspects jointly into consideration, strategies and recommendations were developed in order to assist companies in developing and implementing a sustainable telework policy. For this paper, we limit ourselves to the aspects of the SWOT analysis which are relevant for mobility and environment.

4.1 Impact on mobility
An overview of the key results of the SWOT analysis with respect to the impact of telework on mobility is shown in Figure 2. The main strength of telework in terms of mobility is that it reduces (in the case of telework at the satellite office) or even avoids (in the case of telework from home) the commuting distances and the related commuting times. Figure 3 illustrates that the main transport modes to travel to HQ are car and train. More than 50% of the employees who are allowed to work at home come by car when travelling to HQ. For employees who can work both at home and in a satellite office, this is almost as high. The share of travelling by train when going to HQ is particularly high for satellite office teleworkers (around 70%).

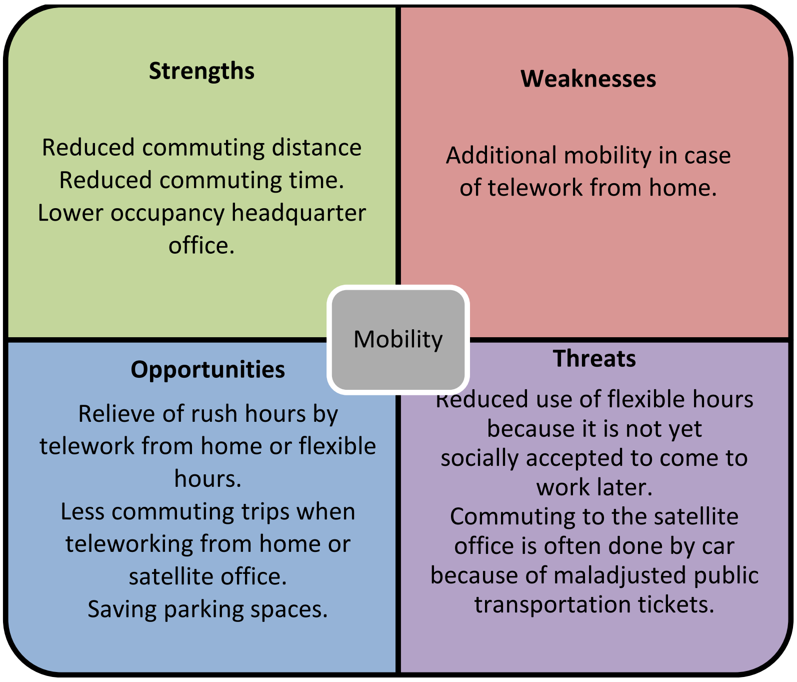
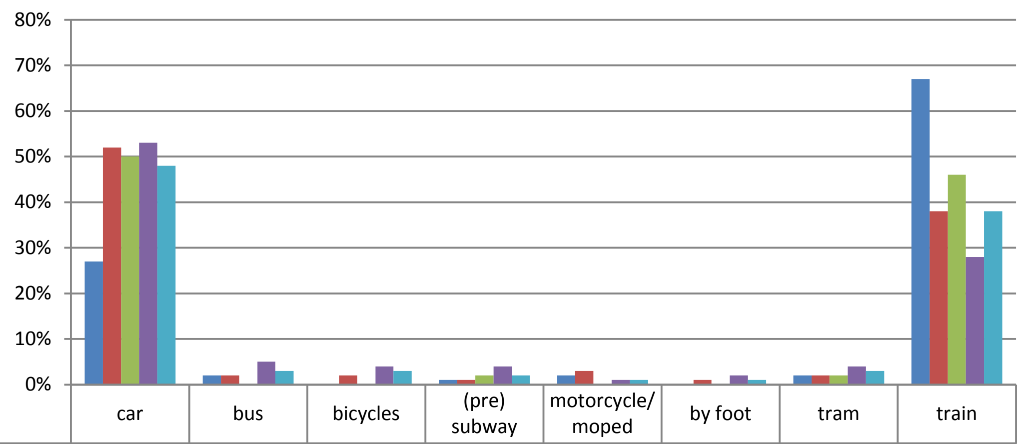


Figure 2. SWOT analysis of the impact of teleworking on mobility (MOBI, 2012)



	car	bus	bicycles	(pre) subway	motorcycle/ moped	by foot	tram	train
Satellite workers	27%	2%	0%	1%	2%	0%	2%	67%
Home workers	52%	2%	2%	1%	3%	1%	2%	38%
Combination	50%	0%	0%	2%	0%	0%	2%	46%
Non-teleworkers	53%	5%	4%	4%	1%	2%	4%	28%
Total	48%	3%	3%	2%	1%	1%	3%	38%

Figure 3. Transport mode to headquarter office (MOBI, 2012)

Both commuting distances and commuting times to HQ are on average higher for teleworkers compared to non-teleworkers. Non-teleworkers travel on average 35 km and 54 minutes to HQ. Satellite office teleworkers have an average commuting distance and commuting time to HQ of 60 km and 91 min, which can be reduced by teleworking at the satellite office to 22 km and 30 minutes. The impact on mobility is of course even higher when teleworking at home. 52% of homeworkers use the car to commute to HQ over an average distance of approximately 45 km and with a related commuting time of 64 min. On teleworking days, these commuting trips can be completely avoided. Teleworking and flexible working hours thus show a clear potential to improve mobility by reducing commuting kilometres and avoiding peak hour traffic.

As suggested by Fuhr en Pociask (2011), the reduced utilization of HQ offices due to telework provides an additional opportunity to promote sustainable mobility by revising the parking policy as part of the parking area can now be used to provide facilities for softer road transport modes (e.g. secured bicycle parking spaces).

Nevertheless, some weaknesses and threats related to telework might offset these positive and sustainable effects. At present, flexible hours are not yet widely used because arriving late at work is often not socially accepted. Another threat stems from the fact that, based on our survey results, commuting to satellite offices often involves a modal shift from train to car, despite the fact that many companies consciously locate their satellite offices near train stations. Figure 4 illustrates that no less than 35% of the satellite teleworkers that commute by train to HQ, take the car when they commute to the satellite office.

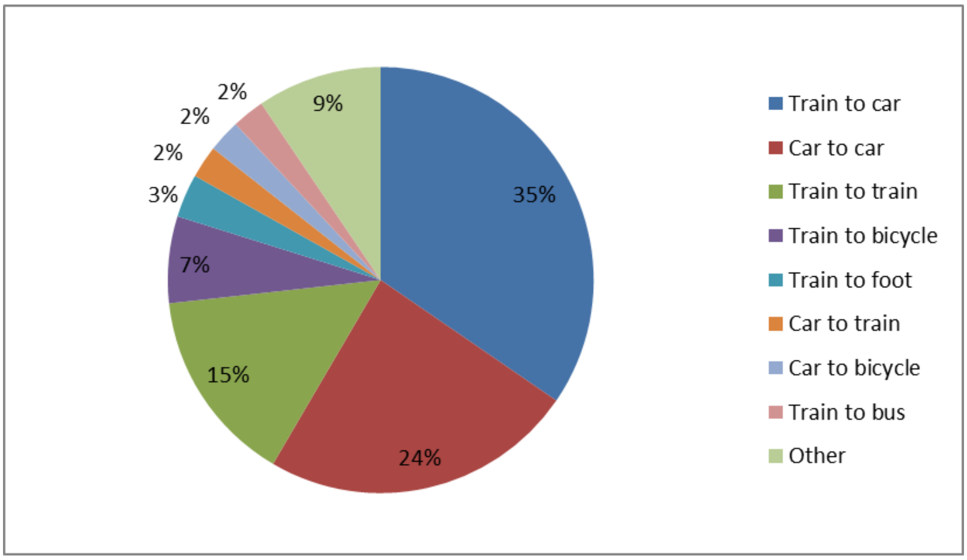


Figure 4. Modal shift of the main transport mode when commuting to the satellite office versus commuting to the headquarter office (MOBI, 2012)[10]

Possible causes for this modal shift are that train travel is considered less efficient for shorter trips, rail connections to satellite offices are usually less direct and/or less frequent than rail connections to the capital (where the HQs in our case study are located), but also lack of flexibility in rail passes, which are in Belgium linked to a certain route. In case the satellite office is not located along the same route to HQ, an additional rail pass needs to be acquired. Cost for this additional pass usually has to be carried by the employee him/herself. On the other hand, modal shifts in favour of more sustainable alternatives also occur, but are smaller in magnitude, i.e. an increase of almost 10% in bicycle use.

Telework at home not only reduces commuting distance and time, but also ensures that peak hour traffic is relieved. A potential weakness however is the occasional car use during the day for non-work related, shorter trips (i.e. shopping). Since only 13% of the respondents that telework from home indicated to make these (generally relatively short) trips, the impact n mobility is limited.

As a result of the above analysis, one can conclude that strategies aimed at promoting telework to achieve a more sustainable mobility, should on one hand focus on stimulating a change of mentality so that use of flexible work hours and regimes are better accepted among colleagues. On the other hand, public transport companies need to accommodate teleworking by providing tailor-made passes, allowing visiting multiple work locations and taking into account occasional

[10] 'train to car' means changing from train to car when commuting to the satellite office as compared to travelling to HQ.

days where employees work at home. The location of the satellite office and its accessibility by public transport is also crucial for their potential success (Nilles, 1995; Van Acker et al., 2007).

4.2 Impact on environment

The environmental impact of telework is mainly twofold. First, there is an environmental impact resulting from changes in mobility. Secondly, additional or avoided energy use in the offices or at home also has an impact. Figure 5 shows the main findings of the SWOT analysis with respect to the environment.

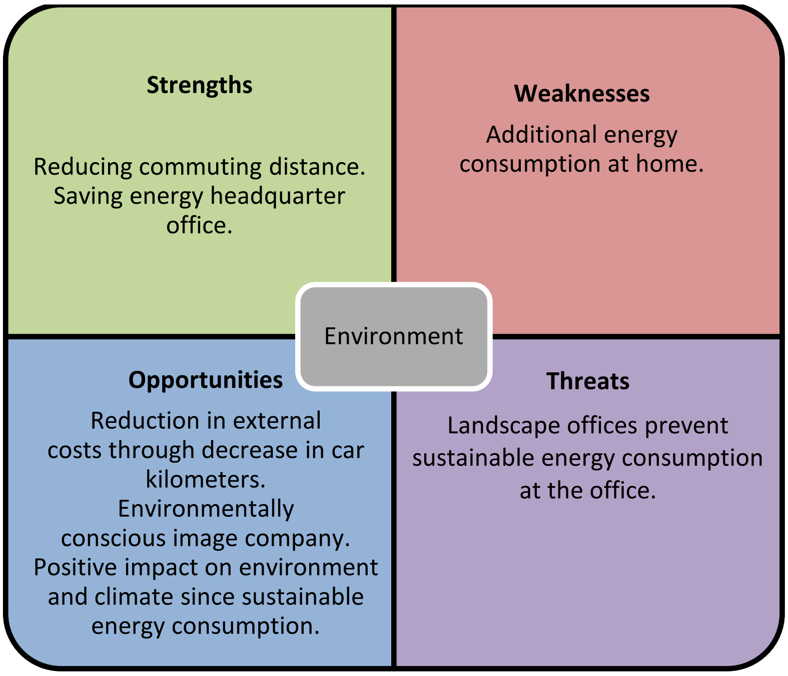


Figure 5. SWOT analysis of the impact of teleworking on the environment (MOBI, 2012)

The reduction of commuting distances as a result of telework has an important environmental impact, especially when a change in car kilometres is involved. Car use causes various environmental and socio-economical external costs (pollution, noise, accidents, etc.) which can potentially be reduced or avoided by telecommuting. These external cost savings are quantified in section 5.

Next to these external environmental cost savings, telework can also generate savings with regards to energy consumption, especially when empty office spaces as a result of telework are dealt with in an environmentally conscious manner. The literature study and research survey were used to examine to what extent telework from home and/or at the office presented extra/less energy consumption due to heating/cooling, lighting and the use of electrical appliances. Energy savings in the headquarter office appeared to be very limited and on average lower than 1%. This is largely explained by the fact that many companies still make use of landscape offices where cooling/heating and lighting cannot be adjusted to the amount of employees actually present at the work floor. On the other hand, the regulatory framework and requirements for office buildings in Brussels are becoming increasingly more stringent with regards to energy consumption and the energy balance of buildings, so savings might increase in the future.

Teleworking also offers additional opportunities to contribute to reducing the carbon footprint of companies if they work with flexible offices or shared workspaces.[11] By using the available office space in a more optimal way, the required office space can be reduced substantially. Research among companies who have implemented flexible offices has revealed that, before implementation, the occupancy rate of their offices in a classical setting was only 65%-70% as a result of meetings, client visits, holidays, illness, telework, etc. Flexible offices allow a more optimal use of the available space, making certain areas or even entire floors redundant so that they can be used for other purposes or in some cases even become obsolete. These areas or floors do not longer need to be heated/cooled or lighted. Moreover, due to the more concentrated use of work space, savings can be gained also on the use of (electric) appliances.[12]

A weakness of teleworking at home is the potential increase in energy consumption due to additional heating/cooling, lighting and use of electronic devices (laptop, etc.) at home, depending on whether or not other persons are present during the day. According to the research survey, 1 out of 4 teleworkers at home have no additional energy consumption because of additional residents. More than half of the homeworkers do indicate energy increases at home as a result of telework, but this increase is rather limited.

In the next section, the impact of telework on transport will be quantified in detail using the concept of external transport costs.

5. External transport cost impacts of teleworking

In order to examine the societal impact of telework, external transport costs were calculated based on the survey data for a) transport to HQ, b) transport to the satellite office and c) additional trips (if any) when working at home. Calculation of external transport costs was limited to car transport, as focus was on identifying the marginal external costs of an additional vehicle that is added to or removed from the existing traffic flow. In the case of transportation by train and other public transportation (bus, tram, subway), it was assumed that a change in the number of passengers as a result of teleworking initially had no impact on the frequency, composition and number of public transport options.

5.1 Transport externalities: theoretical background

Bickel and Friedrich (2005) state that *"An external cost arises, when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group."*. In the transport sector, externalities arise when transport-consumers/producers impose additional costs on society without having to bear these costs themselves or without having to transfer or pay compensations. Transport externalities are primarily related to the societal impacts of emissions (climate change and air pollution), accidents, noise, soil contamination, disruption of the ecological system, infrastructure damages, visual intrusion and congestion (Macharis et al., 2010). Indirect effects of transport, such as energy production (pre-combustion processes), production, maintenance and disposal of vehicles, and production, maintenance and disposal of transport infrastructure, are termed up-

[11] De Croon et al. (2005) consider 'office use' as a dimension of office concepts (next to 'office location' and 'office layout') which refers to the manner in which workplaces are assigned to office workers. The fixed workplace assigns one single workplace to one single office worker, while the shared workplace or flexible office assigns one workplace to a range of office workers. This last concept is also termed desk-sharing.

[12] It should be noted that shared workplaces can have an impact on job performance, job satisfaction and employee health. In their literature review on office use, De Croon et al. (2005) found limited evidence that desk-sharing improves communication between office workers. The evidence that desk-sharing intensifies cognitive workload was however inconsistent. For the effects of shared workplaces on job performance, job satisfaction and health, the evidence was insufficient due to the small number of studies at that period. But it is clear that a company should take these elements into consideration when changing from fixed to shared workplaces.

and downstream processes since they occur before and after the actual vehicle operation. These up- and downstream processes can cause additional external effects such as additional air polluting or climate changing emissions. In order to increase transparency, these up- and downstream related external costs are usually calculated separately. Only pre-combustion processes (well-to-tank emissions linked to extracting, refining and transporting fuels) directly depend on vehicle kilometres travelled and are therefore relevant up-stream related short term marginal external costs (Maibach et al., 2008).[13]

In this paper, calculations of external costs are based on best practices for marginal external cost calculations currently available in economic literature. Despite growing consensus on key methodological issues (Maibach et al., 2008), numerous influencing parameters have to be taken into account when performing a detailed external costs estimation, such as fuel type (petrol, diesel, LPG, biofuels, ...), location (urban, interurban, rural), the driving conditions (peak, off-peak, night) and vehicle characteristics (EURO standards).[14] In this paper, data from the IMPACT study (Maibach et al., 2008) was used to derive key external cost figures.[15]

5.2 Calculation of the external costs: methodology

The impact of telework on mobility is calculated by comparing the external transport costs caused by commuting to HQ with the external transport costs caused by commuting to the satellite office or when working at home. In a first step, the marginal external costs per vehicle kilometre are calculated for each of the three situations (HQ, satellite office and work at home). Multiplying these values with the additional or avoided kilometres driven by car when working at the satellite office or at home compared to commuting to the HQ office allows calculating the impact of telework in terms of external costs. For a realistic and detailed assessment, different telework scenarios were considered based on the results of the survey research, where telecommuting frequency of most teleworkers was found to be around one to two times a week.

The modal choice made by employees is another crucial factor. Since external costs will be higher or lower depending on additional car kilometres driven or avoided, the impact of a modal shift in the main transport mode used for travelling to HQ or satellite office is taken into account.

Location is also an important factor. For air and noise, receptor density, which is determined by the number of people exposed to transport related pollutants or noise, plays a crucial role. In general, the closer to an emission source people are located and the higher the number of people exposed, the more nuisances and health impacts will occur, hence the higher marginal costs will be (Maibach et al., 2008). Congestion is usually also more severe in urban areas and less so in rural areas (De Nocker et al., 2006) Therefore, distinction was made between rural and urban areas for certain external cost categories. Based on the Strategisch Plan Ruimtelijke Economie Vlaanderen (Strategic Plan Spatial Economics Flanders) (Cabus and Vanhaverbeke, 2004), a ratio of 70% urban – 30% rural was chosen for commuter trip trajectories to the HQ in Brussels.

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[13] Note that we calculate the impact of additionally avoided units of cars, which means that we are interested in the marginal rather than the average external costs. In addition, since we assume that the overall transport infrastructure and vehicle fleet remain fixed in the short term, long term marginal external costs are not considered.

[14] For an overview of the calculation of the external costs, see i.e. INFRAS/IWW (2000 en 2004), ExternE, EC (2005), EX-TREMIS, TRT (2007), Forkenbrock (2001), European Commision (2011), Mauch, Banfi en Rothengatter (1995), Maddison et al. (1996), Kreutzberger et al. (2006), Macharis en Van Mierlo (2006). For an overview of the different external cost categories, the most relevant studies in a European context and recommended key figures as proposed by the European Commission, see: Handbook on estimation of external cost in the transport sector (Maibach et al., 2008), developed within the IMPACT study (Internalisation Measures and Policies for All external Cost of Transport).

[15] The European Commission aims to internalize the external costs of transport in order to attain a more sustainable transport system (European Commission, 2011). It refers to the IMPACT study as a basis for countries to develop internalisation schemes.

Trip distances for the main transport mode to HQ and satellite office as well as additional kilometres (if any) when working at home were collected through the survey, differentiated by fuel type.[16] Respondents were also asked to indicate the perceived traffic intensity levels in morning traffic. The results in Table 1 clearly show that commuters to HQ are faced with much higher congestion levels than commuters to the satellite office.

Table 1. Respondents estimation of morning traffic intensity on the way to HQ and satellite office (MOBI, 2012)

Traffic in the morning	HQ	Satellite office
always fluent, no traffic jams	4.0%	29.8%
usually fluent, little congestion	16.8%	51.3%
reasonably fast, but regular traffic jams	25.3%	15.3%
usually difficult, often traffic jams	28.3%	3.6%
very difficult, almost always traffic jams	25.5%	0.0%
Total	100.0%	100.0%

5.3 External costs per vehicle kilometre

Next, total external transport costs per category were calculated for each different work situation (HQ, satellite office and work at home), based on survey results and applying key figures from IMPACT (Maibach et al., 2008). Dividing these totals by the number of vehicle kilometres produces external cost figures expressed per vehicle kilometre for the different external cost categories (Table 2).

Table 2. Marginal external costs of the various external costs categories for the three situations, expressed in 2011 €ct per vehicle kilometre (MOBI, 2012)

Work situation	Climate change	Air pollution	Up-and downstream	Noise	Accidents	Congestion
HQ	0.48	0.70	0.56	0.85	2.83	34.04
Satellite office	0.48	0.58	0.56	1.42	2.83	6.65
From home	0.50	0.68	0.58	1.60	3.08	2.31

For climate change, air pollution and up-and downstream, IMPACT key figures for EURO-4 cars with an engine capacity between 1400 and 2000cc for petrol and diesel were applied[17].

Marginal external climate costs and marginal external costs of up-and downstream processes depend directly on travel related fuel consumption and are therefore comparable per vehicle kilometre for the three situations.

For marginal external costs of air pollution, receptor density is crucial. Because this receptor density is larger in metropolitan areas in the vicinity of the HQ than in (medium) urban areas in the vicinity of the satellite office, marginal external costs of air pollution are on average lower for trips to the satellite office. On the other hand, for longer trips to both HQ and satellite office, parts of the trip will be travelled on highways in less urbanized or rural areas, where local receptor density is lower. When working at home, the additional trips are mainly in urbanized and interurban areas. Receptor density for these additional trips will therefore on average be lower than the receptor density in the (medium) metropolitan areas in the vicinity of headquarter and

[16] Information on the modal choice for the pre- and post-trajectory to the station (train, tram, bus) when public transport is chosen as the main mode of transport was not available in the survey results and this part of the trip could therefore not be included in the analysis.

[17] While the shares of network types applied to the figures in the IMPACT study were:

- Head office: 10% metropolitan roads, 20% inter-urban roads and 70% motorways
- Satellite office: 10% urban roads, 20% inter-urban roads and 70% motorways
- Home: 100% average value reported in IMPACT (since it is unknown where the homeworker is living).

satellite office, but on average higher than the receptor density on parts of the trips to HQ and satellite office through less urbanized or rural areas. Summing these effects up, the marginal external costs of air pollution expressed per vehicle kilometre for additional kilometres when working at home are found to be almost similar to those for commuting to HQ and satellite office.

Marginal external noise costs however are clearly higher for working at home (additional kilometres) and commuting to the satellite office than for commuting to HQ. Here, both receptor density (and hence the rural-urban division) as well as traffic conditions play an important role. During dense traffic conditions, the marginal external noise costs are relatively low, since an additional vehicle will add little to the noise levels caused by the traffic that was already on the road. On the other hand, additional noise nuisance will be relatively high when an extra vehicle is added to a thin traffic flow.

For the marginal external accident costs, specific key figures for personal car use in Belgium from IMPACT were applied, differentiated according to the network level (urban roads, highways, all roads). Since satellite offices are generally located in regional cities and thus urban environments, 70 % of vehicle kilometres were assumed to be travelled on motorways and 30% on urban roads for both commuting to headquarters and satellite offices, resulting in similar marginal external accident costs per vehicle kilometre for both. For working at home, additional vehicle kilometres were assumed to be driven on the category "other ways", leading to slightly higher marginal external accident costs per vehicle kilometre for any additional kilometres travelled when working at home. This is mainly because on motorways (used to commute to HQ and satellite office) relatively far fewer accidents happen per vehicle kilometre travelled, but on the other hand those accidents are usually much more severe due to higher speed.

The marginal external congestion costs are also based on IMPACT key figures (Maibach et al., 2008), where a division is made between different network types and congestion levels. Table 1 already showed that commuting by car to HQ involves a relatively large number of vehicle kilometres in dense traffic conditions, namely 79% of the total travelled kilometres, while only 21% is travelled in easy traffic conditions. For commuting to the satellite office these ratios are almost reversed: only 19% of the vehicle kilometres are travelled in dense traffic conditions, while the remaining 81% are in fluent traffic conditions. Hence, the marginal external congestion costs of commuting to HQ are considerably higher than those of commuting to satellite offices. For work at home, the marginal external congestion costs are relatively small.

5.4. Calculation of the external costs: assessment scenarios

Based on the external costs per vehicle kilometre calculated above, the impact of telework for the employees who participated in the survey research was estimated. This has been done for each of the three situations (HQ, satellite office and work at home) by multiplying the marginal external costs per vehicle kilometre (Table 2) with the additional or avoided car kilometres driven according to the survey research.

For each type of telework (work at home and at the satellite office), the following 4 scenarios were established:

- Scenario 0: no telework (baseline scenario)
- Scenario 1: 1 day / week telework (1/5 scenario)
- Scenario 2: 2 days / week telework (2/5 scenario)
- Scenario 3: always telework (maximum scenario)

The impact of teleworking can then be calculated by comparing the results of scenario 1 and scenario 2 to the reference scenario 0. Scenario 3 is an extreme scenario in order to provide an indication of the maximum impact if telework would be possible at all times.

Satellite office work

Figure 4 already indicated that a large number of modal shifts occur when employees commute to the satellite office in comparison with the transport mode used to commute to HQ. Table 3 shows the main modal shifts and respective average commuting distances to HQ and satellite office for a one-way trip. [18]

Table 3. Modal shift, number of respondents (total and percentage) and average number of vehicle kilometres for commuting to HQ and to satellite office by satellite office workers (MOBI, 2012)

			Average number of km (one way trip)	
Modal Shift	Number	%	HQ	Satellite office
Train to car	84	34.6%	75	21
Car to car	58	23.9%	73	28
Train to train	36	14.8%	83	26
Train to bicycle	16	6.6%	73	7
Train to walk	8	3.3%	70	1
Car to train	6	2.5%	60	35
Car to bicycle	6	2.5%	48	10
Train to bus	6	2.5%	86	10
Others	23	9.5%		
Total	243	100.0%		

When commuting by car to HQ, high external costs are encountered, mainly due to the high congestion levels present in morning and evening peak traffic in and around Brussels. Since congestion levels are much lower when commuting by car to the satellite office, and distances are also shorter (which also effects environmental costs), external costs generated by one and two days of satellite work are respectively 17.6% and 35.1% lower compared to the baseline scenario with no teleworking. If working at the satellite office would be possible for the whole week, maximum savings could reach 87.8%.

The situation is however completely different when a modal shift occurs from train or public transport to car when commuting to the satellite office. Based on the survey research, this modal shift occurs for 34% of respondents. Assuming that teleworking has no impact on railway operations, no marginal external costs occur when commuting by train to HQ. Commuting by car to the satellite office however does impose marginal external transportation costs on society. This type of modal shift therefore causes a significant increase in external transport costs when working at the satellite office.

Approximately 2.5% of the satellite office employees commute by car to HQ but use the bike to travel to the satellite office, another 2.5% use the car to get to HQ but commute by train to the satellite office (again, no immediate impact on railway operations is assumed). In both cases there is a significant external cost saving due to teleworking in satellite offices, since savings here involve avoiding the densely congested commuter route to and from Brussels. And this is not taking external health benefits associated with cycling into account.

14.8% of satellite office workers make both trips (to HQ and satellite office) by train, respectively 6.6% and 3.3% of them commute by train to HQ but travel with bike and by foot to the satellite office, and 2.5% take the train to reach HQ and commute by bus to the satellite office. For these categories, no changes in external transport costs are assumed.

The weighted overall effect of working at the satellite office based on the survey results was calculated taking into account the relative weights of the various modal categories, including the categories in which no external costs occur. Table 4 clearly shows an external transport cost

[18] Only the main transport mode was considered: distances of pre- and post-trajectories (i.e. to and from railway stations) are not included.

saving due to satellite office teleworking. Compared to scenario 0 with no teleworking, the average external cost saving due to scenario 1 (one day teleworking in satellite office) is on average 15.6 %, while it rises to 31.2% for scenario 2 (two days teleworking in satellite office). This has mainly two reasons: shorter commuting distances to the satellite office, having a positive impact on all external cost categories, and much lower congestion levels encountered when commuting to satellite office by car. For scenario 3 (five days teleworking in satellite office), external costs savings rise to 78%.

Table 4. Marginal external costs for teleworking at satellite office per employee per week (€ 2011): weighted average of modal categories (MOBI, 2012)

SATELLITE weighted	Climate	Air	Up- & down	Noise	Env.	Diff. from Sc 0	Accidents	Cong.	TOT incl C	Diff. from Sc 0
€ per employee per week										
Scenario 0 (5d HQ)	0.97	1.41	1.12	1.71	5.21		5.68	68.38	79.27	
Scenario 1 (1d SO + 4d HQ)	0.91	1.29	1.05	1.77	5.01	-0.20 (-3.7%)	5.33	56.56	66.91	-12.36 (-15.6%)
Scenario 2 (2d SO + 3d HQ)	0.85	1.17	0.98	1.82	4.82	-0.39 (-7.4%)	4.99	44.74	54.54	-24.72 (-31.2%)
Scenario 3 (5d SO)	0.67	0.81	0.79	1.98	4.25	-0.96 (-18.4%)	3.94	9.27	17.46	-61.81 (-78.0%)

HQ: headquarter office / SO: satellite office

Noise is the only external cost category that increases when teleworking at satellite offices. Since marginal external noise costs are significantly higher in less dense traffic conditions, even lower commuting distances to the satellite office cannot prevent noise costs to be slightly higher for scenarios with teleworking. However, adding all external environmental costs together (climate change, air pollution, upstream and downstream processes and noise), working at the satellite office still results in a cost saving of 3.7% (scenario 1) and 7.4% (scenario 2). In the case of five days working at the satellite office, the marginal external environmental costs could be reduced by 18.4%.

Overall, the external cost impact will depend mainly on the proportion of commuter trips to HQ taking place by car and on modal shifts occurring when commuting to the satellite office. The more car trips to HQ are replaced by trips to the satellite office (preferably by other transport modes) and the lower the modal shift shares of switching to car use for commuting to the satellite office, the larger the external cost savings will be.

Work at home

The impact of working at home on external transport costs is calculated by comparing trip behaviour to HQ with additional trip behaviour during an average day working at home. Similar as above, modal choice data collected as part of the survey research was used.

The survey results show that home workers commute in different ways to the HQ on non-teleworking days. When commuting to HQ by car, external cost savings of teleworking at home can be large. However, when commuting to HQ by train, any additional car kilometres made during working at home days will have a negative impact. Table 5 shows the main transport modes and respective average distances for commuting to HQ by home teleworkers.

For employees working at home, any additional private car kilometres that would not have been driven when working at HQ should be taken into account. A literature review by Walls and Safirova (2004) stated that not only commute car kilometres decreased for homeworkers, but even non-commute car kilometres in some cases. Overall, no study reviewed by Walls and Safirova showed a significant increase in non-commute travel for teleworkers, suggesting that additional kilometres, if present, are limited at most. This is confirmed by our survey results: only 13% of the employees working at home use the car when working at home, and only 42% of these 13% state explicitly to travel additional private car kilometres with an average distance of 12.3 km per employee involved.[19]

Table 5. Modal choice, number of respondents (total and percentage) and average number of vehicle kilometres with main mode of transport for commuting to HQ by home teleworkers (MOBI, 2012)

Modal choice to headquarter	Number	%	Average number of kilometres to headquarters
Car	232	51.3%	40
Train	177	39.2%	62
Motorcycle / moped	10	2.2%	31
Tram	10	2.2%	11
Subway	5	1.1%	28
Walk	2	0.4%	3
Bicycle	9	2.0%	14
Bus	7	1.5%	26
Total	452	100.0%	

About half of homeworking employees (51%) commute by car to HQ over an average commuting distance of 40 kilometres. Compared to satellite workers, external transport costs for scenario 0 (5 days commuting to HQ) for homeworking employees is lower due to a lower average commuting distance. In scenario 3 (five home working days), no marginal external transport costs occur if no additional car kilometres are driven. If there are additional car kilometres, marginal external transport costs will still be very limited given the low trip distances.

When teleworkers commute to HQ by train, this is however completely different. Assuming no impact of teleworking on railway operations, there are no marginal external costs when commuting by train to HQ. If during teleworking at home no additional car kilometres are driven, no marginal external transport costs occur there either. If however additional car kilometres are driven when homeworking, a negative external cost impact does occur. But even in scenario 3 (5 days' work at home), these additional external costs are limited due to the relatively low distances of additional trips. Moreover, as only a very small group of homeworkers in the survey stated to travel additional kilometres (5.4%), the overall impact of this category on external costs remains relatively limited.

When commuting with tram, metro or bus to HQ, the impact will be similar as for commuting by train. When commuting to HQ by foot or bicycle health benefits could even occur, but since these modal choice categories are relatively small, impact will be limited. Commuting by

[19] The survey made a distinction between car trips for business and private purposes. It explicitly asked teleworkers to state additional vehicle kilometers travelled for business and private trips by car when working at home. For private trips distinction was therefore made between private trips that are shifted in time (e.g. shifting shopping trips from evening to the daytime), and additional private trips (where it was explicitly asked to exclude trips that would be executed at another moment in time). In order to help respondents to understand this correctly the example was given of bringing kids to school by car when working at home while they go by bike when working at the office. For business purposes distinction was made between business trips that are shifted in time and "real" additional business trips that are done extra when working at home. Here the example was given of visiting clients with public transport when working at the office but by car when teleworking at home. The survey also asked detailed questions on the travel patterns (e.g. possible detour kilometers for shopping or school when going to or from work). In this way, differences in vehicle kilometers driven by car for the 3 scenarios (working at HQ, at the satellite office or at home) were mapped in detail.

motorcycle/moped to HQ represents 2.2% of telecommuters in the survey. Here external costs are generally higher than when using the car due to relative high noise emissions and accident risks, but given the small amount this group was included within the car category.

Summary
The weighted overall effect of teleworking at home based on the survey results was calculated taking into account the relative weights of the various modal categories, including the categories in which no external costs occur. Table 6 clearly shows that teleworking at home can offer significant external transport cost savings. Compared to scenario 0 with no homeworking, the average external cost saving due to scenario 1 (one day working at home) is on average 19.9 %, and rises to 39.9% for scenario 2 (two days working at home). For scenario 3 (five days working at home), external transport cost savings amount to 99.6%.

Table 6. Marginal external costs by working at home per employee per week (€ 2011): weighted average of the modal categories (MOBI, 2012)

HOME (weighted)	Climate	Air	Up- & down	Noise	TOT (Env.)	Diff. from Sc 0	Accidents	Cong.	TOT incl. C	Diff. from Sc 0
€ per employee per week										
Scenario 0 (5d HQ)	1.04	1.50	1.19	1.83	5.56		6.07	73.03	84.65	
Scenario 1 (1d WH + 4d HQ)	0.83	1.21	0.96	1.47	4.47	-1.09 (-19.6%)	4.88	58.79	67.79	-16.87 (-19.9%)
Scenario 2 (2d WH + 3d HQ)	0.63	0.91	0.72	1.12	3.38	-2.18 (-39.1%)	3.68	44.54	50.92	-33.74 (-39.9%)
Scenario 3 (5d WH)	0.02	0.02	0.02	0.06	0.12	-5.44 (-97.8%)	0.11	0.08	0.31	-84.34 (-99.6%)

HQ: headquarter office / WH: working at home

There are two main reasons for the external transport cost savings generated by homeworking. First, complete avoidance of commuting distances, which has a positive impact on all external cost categories, including noise. And second, significantly lower congestion levels for any additional car kilometres travelled during telework at home compared to congestion levels encountered on commuting trips to HQ.

Summing up the external environmental costs (climate change, air pollution, upstream and downstream processes and noise) shows external cost savings of 19.6% and 39.1% for respectively scenario 1 (one day working at home) and scenario 2 (two days working at home). In case of scenario 3 (five days working at home), savings rise to 97.8%. These savings are much higher than for satellite office teleworking, since homeworking avoids a lot more car kilometres and consequently fuel consumption than satellite office working. External cost savings of teleworking at home are therefore on average larger than those of teleworking at satellite offices.

6. Conclusions and recommendations

In this paper, focus was on the societal impact on mobility and environment of teleworking in companies with headquarters located in the Brussels Capital Region. Rather than focusing on the possible benefits and shortcomings on the individual and organizational level in the framework of Baruch (2000), attention was directed to the benefits and shortcomings of mobility related aspects of teleworking on the societal level. Indeed, telework, the time and place independent work by using information and communication technologies (ICT), offers the possibility to avoid and/or reduce commuting trips. In this way, telework can contribute in a direct way to a reduction of mobility related problems and environmental costs. However, under certain conditions, teleworking can also lead to extra mobility and energy consumption, while employees can be confronted with additional transport costs.

The major advantage of teleworking from a mobility perspective is that it enables the reduction of commuting distances and times. The resulting benefits can be identified on several levels. On a traffic level, trips can be avoided, postponed or reduced, relieving the congested peak hours. On an environmental level, avoidance and/or reduction of car kilometres leads to a significant decrease in associated external effects which are detrimental to society (emissions, noise, etc.). These benefits are of course only true to the extent that the concept of constant travel time budgets does not hold. Otherwise the decrease in travel time and environmental damages by eliminating commuter trips through teleworking might be compensated by increasing travel distances and environmental effects caused by other trips, seriously limiting the potential of telework to improve mobility. Our survey results however do not support the suggestion of a replacement of avoided commuter trips by significant additional travel distances on an individual level.[20]

Analysis of the external transport costs clearly demonstrates that teleworking in companies in the Brussels Capital Region can provide a significant external transport cost saving for society. Especially by avoiding car commuter trips to Brussels, a decrease in marginal external congestion costs can be achieved. Also individual time costs can be reduced significantly, since teleworkers can totally or partly avoid congestion by teleworking.

The largest gains can logically be realized by homeworking, since commuting trips can be avoided completely. But scenarios are possible where teleworking at home may increase marginal external transport costs, namely when commuting to HQ is performed by public transport or a soft mode and when additional private car kilometres are driven when homeworking. Our survey results however confirm claims in literature that this additional external cost impact by homeworking, if it occurs, is relatively small.

When teleworking at satellite offices, a modal shift from public transport or soft mode (commuting to the HQ) to car (commuting to the satellite office) potentially reduces total external transport cost savings. Overall, teleworking at satellite offices shows however a positive contribution to sustainable mobility.

The potential of external cost savings depends mainly on the proportion of commuting trips to HQ by car. The more car trips to HQ are replaced by working at home or at the satellite office, the larger the external cost saving will be. On the other hand, negative modal shifts from public transport or soft modes to car when travelling to the satellite office, are to be avoided.

So, essentially, the size of the impact on environment and sustainable mobility of teleworking depends to a large extent on a successful reduction of car use. Companies can facilitate discouraging car use when more sustainable alternatives are available through their mobility policy. Also transport operators have a responsibility by adapting their ticket policy to better match with the flexibility of teleworking. Obviously, the impact of telework on sustainable mobility will depend on the type of telework: teleworking at home for a full day is logically a more sustainable form of telework than working at a satellite office because the commuting trip can be avoided completely when homeworking.

Homeworking however also has limits, showing both benefits and drawbacks, for employees as well as employers. Working at home is only possible for certain types of work. On a social level it is important to avoid social isolation and to assure a good work-life balance in order to prevent

[20] Effects on a more aggregated level, where less congested roads due to teleworking might lead to longer travel distances by users of the transport system, would require further research.

demotivation and loss of productivity. It is therefore recommended to telework part-time, limiting teleworking to a number of days per week or month. Our survey results showed that employees find one or two teleworking days per week sufficient. Based on the external cost savings calculated in this paper, we can conclude that implementing telework in this form on a larger scale could significantly contribute to a more sustainable mobility.

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