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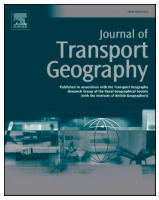

Work flexibly, travel less? The impact of telework and flextime on mobility behavior in Switzerland

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ABSTRACT

There is an ongoing discussion about the impact of flexible forms of work on travel behavior. Though it is generally accepted that telework decreases distance commuted, there are mixed conclusions about the notion that non-work-related journeys could be offsetting any saved commute. This paper investigates the influence of two flexible working arrangements – namely telework and flextime – on commutes, non-work traffic, and peak-period travel in Switzerland. Using the 2015 Swiss Mobility and Transport Microcensus (MTMC), this study analyzes flexible working arrangements with respect to their effects on traffic. The results show that people who work partly from home – compared to those who never telework – do indeed commute less; however, their non-work travel increases. This rebound effect completely offsets the saved commutes, resulting in a zero impact on the total distances covered. Only people who work exclusively remotely show less total mobility compared to those who never telework. However, only a small minority of people work only from home, with most teleworkers combining working on-site with some degree of working from home. Moreover, this study finds only slight potential for relieving traffic congestion through flexible working arrangements: Whereas teleworkers are less likely to commute during evening peak periods, people working flextime are even more likely to commute during morning rush hours. Hence, the distinction between morning and evening peak periods should be taken into account in future studies. Furthermore, research on flexible working arrangements and travel behavior benefits from the consideration of both non-work travel and total travel as well as the separation of part-time from full-time telework.

1. Introduction

In accordance with the Paris Agreement (United Nations Framework Convention on Climate Change UNFCCC, 2015) Switzerland adopted its long-term climate strategy at the beginning of 2021 (Swiss Federal Council, 2021): Greenhouse gas emissions should be halved by 2030, and by 2050, Switzerland is aiming to reach net zero greenhouse gas emissions. Currently, the transport sector (without air transport) is responsible for almost a third of Switzerland's greenhouse gas emissions (Swiss Federal Office for the Environment FOEN, 2021). Hence, it is advisable to reduce the volume of traffic and congestion. However, traffic in general and motorized private transport (MPT) in particular is increasing and this is expected to continue, mainly due to population and economic growth (Swiss Federal Office for Spatial Development ARE, 2016). Regarding MPT, regular traffic jams and congestion have been an issue in Switzerland for the last 20 years and are projected to continue to increase throughout the coming decades Swiss Federal Department of the Environment, Transport, Energy and Communications DETEC and Swiss Federal Roads Office FEDRO, 2018). In 2019, there were about 30,000 traffic jam hours, of which 89% were tracked back to a capacity overload (Swiss Federal Roads Office FEDRO, 2020). As data from 2015 shows, this entails costs for additional time as well as environmental, climate, energy, and accident costs due to traffic jams to the tune of 1888 million CHF (about 2060 million USD) (Keller, 2019).

Road capacity overload is particularly noticeable during rush hour, from 7 a.m. to about 9 a.m. and from 5 p.m. to 7 p.m. Not only are many commuters affected by this congestion, but they are also part of the problem (Swiss Federal Roads Office FEDRO, 2020; Swiss Federal Statistical Office, 2021). In Switzerland, 4 out of 5 labor market participants are commuters, totaling about 3.6 million people, of which 51% commute by car (Swiss Federal Statistical Office, 2021). Therefore, changes in commuting behavior are an important factor in fighting traffic-related greenhouse gas emissions.

The ongoing digitalization and the proceeding development of internet-based information and communication technologies (ICTs) also

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changes the Swiss labor market (e.g. Meissner et al., 2016). The spread of ICTs is making gainful employment more flexible via the increasing use of e-mails, online conferences or VPNs, for instance. Correspondingly, temporal flexibility in the form of flextime and spatial flexibility in terms of working remotely are also present on the Swiss labor market. Additionally, the COVID-19 pandemic has strongly promoted telework in Switzerland via Federal Council-imposed obligations that people work from home whenever possible. The amount of home-working increased due to this rule, suggesting that there is still untapped potential in offering flexible working arrangements more widely. This development could have a positive impact on traffic in two ways: First, the spread of ICTs could eliminate commuting to the workplace on a regular basis, which could reduce traffic overall. Second, the transport infrastructure reaches its limits predominantly during the morning and evening rush hours, while its capacities are less utilized during the rest of the day. Hence, it could be that a more even temporal distribution – promoted through flextime – could reduce the necessity for expanding national road infrastructures. Accordingly, the research question of this study is whether the digitalization of the labor market contributes to reductions in traffic and a better use of transport infrastructure. In particular, this study focuses on the effect of telework and flextime on commuting and travel behavior.

Previous research on this topic is inconclusive (e.g. Hook et al., 2020). While it is widely agreed that flexible working arrangementds distribute traffic more evenly and reduce commuting (e.g. Andreev et al., 2010; Asgari and Jin, 2018; Elldér, 2020; Haddad et al., 2009; He, 2013; Hook et al., 2020; Kim, 2017; Lachapelle et al., 2018), their impact on the total distances traveled is less clear. This is mainly because some studies find evidence for travel reduction through telework (e.g. Elldér, 2020; Mokhtarian et al., 2004) while others do not or even observe increasing impacts (e.g. de Vos et al., 2018; Chakrabarti, 2018; Kim, 2017; Zhu and Mason, 2014; Ravalet and Rérat, 2019). Moreover, studies often have some of the following weaknesses. For example, they are spatially limited to certain metropolitan areas (e.g. Asgari and Jin, 2018; Hu and He, 2016; Kim, 2017; Mokhtarian et al., 2004) or restricted to a specific part of the working population such as white collar workers (e.g. Kim et al., 2015). Some other studies only analyze the commuting time as a proxy for the distance covered (e.g. de Vos et al., 2018; Lachapelle et al., 2018). Yet others are based on imprecise distance measures such as Euclidian distances (e.g. Kim, 2017) or they only use categorical indicators for high and low amounts of travel (e.g. Chakrabarti, 2018). Some studies analyze one-way distances that do not capture the total traffic volume (Hu and He, 2016; Zhu, 2013) or analyze the commute only, and leave non-work travel out of consideration (e.g. Mokhtarian et al., 2004). Finally, some conclusions rely on specific assumptions about travel behavior and frequencies (e.g. Ravalet and Rérat, 2019). In comparison, this study aims to provide a detailed assessment of possible rebound effects and the potential to reduce and redistribute traffic through flexible working arrangements. For this purpose, a nation-wide sample with precisely measured trips is used to analyze the impact of telework and flextime on commutes, non-work travel, total distances covered and rush hour drives from a behavioral perspective.

Switzerland is an interesting and appropriate case to investigate the research question and adds to the literature for two reasons: First, the infrastructure is well developed. This is true for the ICT infrastructure as well as for the public transport system, which provides a viable alternative to motorized private transport in Switzerland. Second, the biggest economic sector in Switzerland is the tertiary sector (mainly consisting of services) (Swiss Federal Statistical Office, 2020), which is generally suitable for ICT usage, and hence, offers a good prerequisite for flexible working arrangements. The potential positive impact of ICTs and flexible working on the environment and the economy is highly anticipated in official reports (e.g. Swiss Federal Roads Office FEDRO, 2019) and forms the basis for various pilot projects and studies in Switzerland (Ecoplan, 2015; Perch-Nielsen et al., 2014; Weichbrodt et al., 2013). However, nationwide research on this topic using a completely behavioral approach is scarce.

The research question is addressed by using the Swiss Mobility and Transport Microcensus (MTMC) of 2015 – a nationwide representative micro-data trend survey on mobility behavior (Swiss FSO - Federal Statistical Office and Swiss ARE - Federal Office for Spatial Development, 2017a). This database allows the combining of information about travel-related behavior with temporal and spatial working conditions, considering socio-demographic, socio-economic and spatial factors. To answer the research question, multivariate regression analyses are used to estimate the effects of flexible working arrangements on different mobility measures (including commuting distance, non-work travel and rush hour commutes).

The remainder of this article is divided into four sections. The next section reviews some similar studies examining the relationship between flexible forms of work and their impact on mobility behavior, and elaborates the research hypotheses. Following that, section 3 describes the data, the operationalization and the analytical strategy used to answer the research question. Thereafter the results are presented. Finally, the paper closes with a conclusion and discussion of the results.

2. Literature review and research hypotheses

The digitalization of the labor market allows and promotes an abundance of different flexible working arrangements in Switzerland, such as telework, flextime, mobile work, desk sharing, part-time work, job sharing or crowdsourcing (e.g. Meissner et al., 2016). The subjects of the following analyses are telework and flextime. Both are forms of flexible working arrangements, which allows labor market participants to decide to some degree when and/or where to work. In this paper, telework is defined as working from somewhere other than the workplace, and in particular from home. In the following, flextime refers to the fact that the working hours are not completely predetermined, so that the worker enjoys some degree of scheduling flexibility. There are various conceptualizations and terms for these flexible working arrangements. Telework is also known as remote work, telecommuting, flexible work, flexplace, distance work, and hybrid work, while flextime can also be called flexible work schedule, schedule control or flexitime (Allen et al., 2015; Mokhtarian, 1991a). This section continues with an overview of the relationship between telework and travel behavior, then presents studies about flextime and traffic, and closes with three research hypotheses.

Since the 1970s, there has been research and an ongoing discussion about the impact of telework on energy use, commuting behavior as well as on general travel patterns (see overviews: e.g. Salomon, 1986; Mokhtarian, 1991b; Walls and Safirova, 2004; Andreev et al., 2010; Hook et al., 2020). The hope is that remote work replaces commuting journeys, which would save greenhouse gas emissions and hence, be beneficial for the environment. This relation is often discussed as substitution effect (Salomon, 1985, 1986). In contrast to this, telework and traffic could take the form of a complementary relationship, meaning that remote work also induces traffic, e.g. in the form of trips for other purposes or by changes in land use (Andreev et al., 2010; Salomon, 1986). Alternatively, the spread of telework could result in modifications to travel patterns, possibly in turn resulting in a neutral impact on traffic (Andreev et al., 2010). Presumably, modification as opposed to reduction is more likely (Salomon, 1985). However, which of these relationships between telework and travel is true, can be answered empirically.

Initially, telework was found to be a promising solution that reduces both traffic and greenhouse gases. An overview of early US remote work pilot projects concluded in 1991 that remote workers indeed commute less, and their non-work-travel does not increase (Mokhtarian, 1991b). About a decade later, another paper reviewed six recent empirical studies and came to the similar conclusion that telework reduces the number of daily trips as well as the commuting distance traveled by car,

and does not affect non-work-travel (Walls and Safirova, 2004). Both studies acknowledge though that more large-scale and long-term research is needed, because it is the number of people who work remotely and to what extent which will determine the total environmental impact. In 2010, one review considered more than 30 empirical studies from the United States and Europe (Andreev et al., 2010). Overall, it confirms substitution effects of telework on different travel indicators such as miles traveled (both generally and by car), the number of commutes or the avoidance of morning peak hours in the short term. Nevertheless, the conclusion is less clear for long-term effects due to possible relocation choices or induced travel and because of a lack of wide representative data (Andreev et al., 2010).

In contrast to these early findings, more recent results are inconclusive nowadays. As early as the beginning of the 2000s, Black (2001) questioned the traffic-reducing influence of the ever-expanding telework practice in cities. He even called this notion a myth and argued in a complementary manner that remote work offers more time and space flexibility, so that the availability of travel opportunities is likely to entail more traffic. He also assumed that a substitution of personal travel demand with virtual interactions due to the increasing usage of advanced ICTs was only wishful thinking. Lane (2019) revisits this essay nearly 20 years later and concludes by reviewing a selection of contemporary studies that (at least for the developed world) these two theses have indeed turned out to be more myth than truth.

Today, the evidence on the impact of remote work on commuting and general travel behavior is mixed, ranging from a substitutional influence (travel reduction), through to no effect, to a complementary impact in terms of induced travel. A recent systematic review by Hook et al. (2020) compares the relationship between telework on various energy consumptions indicators such as commuting, non-work travel and home energy use. This review includes 39 different empirical studies carried out since 1996, based on quantitative analyses of survey data (19), scenario modeling (14) and evaluations of pilot studies (6). Although most of the studies (26) report some energy savings through less commuting, they mostly rely on small samples and often only consider the commute itself. In contrast, the review concludes that the more rigorous studies with a broader scope (e.g. nationwide samples), which also contemplate other indicators such as non-work travel, usually find smaller savings or even an increase in energy consumption. Most studies are from the United States, which could influence the results, since the private car commute is most prominent there and public transport plays only a minor role. Moreover, vehicles and buildings tend to be larger and are less energy-efficient than in other countries (Hook et al., 2020: 7). Hence, the following detailed literature review focuses on recent and empirical survey research from different parts of the world, which considers more indicators than the commute alone.

A study by Zhu (2012) uses the US National Household Travel Surveys from 2001 and 2009 to investigate commuting behavior and non-work trips. It concludes that telework has a complementary effect on travel behavior. Using the same US National Household Travel Surveys, Zhu and Mason (2014) again find no travel reduction for remote workers compared to on-site workers concerning their daily work and non-work vehicle miles traveled. A further investigation by Zhu (2013) also showed on average longer one-way commutes of teleworkers compared to on-site workers for both one- and two-worker households in the US.

Research by Chakrabarti (2018) also makes use of the 2009 US National Household Travel Survey to evaluate, among other things, the effect of regular and occasional telework on the vehicle miles traveled. The study finds a shift to more active and environmentally friendly travel modes such as walking/cycling on remote working days. However, on an annual basis teleworkers are more likely than on-site workers to drive >20,000 miles per year (which corresponds to the top 10% of the annual miles driven in the US). A remote worker's one-way commute is on average 4 miles longer than that of on-site worker's, thus, offsetting saved miles on non-teleworking days. A former study of Mokhtarian et al. (2004) also finds longer one-way commutes for teleworkers as compared to on-site workers. Nonetheless, they observe on average fewer miles commuted by teleworkers measured on a quarterly per capita basis. However, these results are based on a teleworking pilot sample from California and only consider the commuting distance, and not the total distance traveled. A study from Hu and He (2016) uses the 2008 regional household travel survey from the Chicago metropolitan area to analyze the one-way commuting distance of workers as well as the daily total trip duration on the household level. As in the other studies, they observe a longer one-way distance between home and the workplace for people who occasionally work remotely compared to on-site workers. A special feature of this study is that the authors record whether a person teleworked. They find that the daily total trip duration is indeed shorter on teleworking days. Nevertheless, and in contrast to this, telework is generally associated with more time spent on the road during the day, suggesting longer distances traveled and therefore a complementary effect.

Most studies reviewed so far are based on data from the US. Next, research from other countries is presented, starting with two studies from South Korea using data from the 2006 Household Travel Survey in the Seoul Metropolitan Area. A study by Kim et al. (2015) analyzes the impact of telework for white-collar workers on the commuting and non-work distance traveled. As a special feature, they measure the same travel indicators for the household member(s) to investigate any intra-household dependencies of teleworking heads-of-household compared to full-time and part-time office workers. The study shows that although commuting by the teleworking head-of-household is reduced, their trips for other purposes as well as journeys made by their household members offset the saved commute. One reason is that the car is made available to other household members on remote working days in households with only one vehicle. Two years later, a similar study by Kim (2017) again shows that the saved commute of teleworking household heads is offset by a rebound effect of their own behavior and that of their household members. Moreover, this additional travel is mainly covered by car. However, one point of criticism is that only Euclidian distances between travel zones were observed, rather than true distances between origin and destination.

A panel study from the Netherlands by de Vos et al. (2018) finds that teleworkers compared to on-site workers, accept on average 5% longer commuting times. Because commuting time and distance are likely correlated (Hook et al., 2020), this could indicate that teleworking does not reduce travel and is associated with longer commutes due to sorting preferences. The results of a Swedish study by Elldér (2020) using nationwide micro-level travel data suggest that part-day and full-day telework lead to different outcomes. Whereas people who work exclusively remotely on the survey day do indeed travel less, it is the exact opposite case for hybrid workers who do part of their workload from home, but also commute to the workplace. However, the study concludes that overall, telework does reduce the travel demand – because the increase of part-day remote working is less than the decrease of the full-day teleworkers. This result is in contrast to the main findings of the review study by Hook et al. (2020) and the other studies presented. This is surprising, since the results of Elldér (2020) are very reliable, because it was directly measured whether a person teleworked and to what extent. Moreover, the results are based on large scale national transport surveys using different dependent travel indicators.

Looking to Switzerland, an analysis by Ravalet and Rérat (2019) also evaluates the impact of telework on different mobility aspects using the Swiss Mobility and Transport Microcensus (MTMC). Indeed, they find that people who work remotely live on average farther away from their workplace compared to on-site workers, and that this difference increased from 2010 to 2015. Moreover, the authors try to identify people, who actually worked from home on the target day, because this is not part of the survey. Actual remote work was counted as when fulltime-working employees spent at least 6 h at home between 9 a.m. and 5 p.m. on a weekday. They find that teleworkers travel more on average if they commute to work than on a day working from home.

However, it could be that this result is observed due to the modeling approach, because being at home for eight hours also excludes traveling for other purposes such as leisure or shopping during that time.

Allen et al. (2015: 61) suggest isolating the effect of telework on travel patterns from the impact of flextime. Hence, in the analyses that follow, flextime will be included. Additionally, flextime in itself may be a helpful tool for studying congestion. While telework cannot replace commuting in some cases, flextime could help to distribute traffic more evenly throughout the day, which might mitigate rush hour traffic jams. An analysis by He (2013) of the two most congested areas in California shows that flextime workers were less likely to depart before or during peak-period and more likely to start their way to work after the morning rush hour. Not every remote worker works from home all day; there are hybrid workers who work only a part of the day from home. Although the commute is not replaced, part-time telework still offers the advantage of avoiding rush hour if people work from home for a number of hours and commute to the workplace afterwards (Lyons and Haddad, 2008). A study by Haddad et al. (2009) from the UK compares part-day teleworking with full-day teleworking and concludes that the former is more common and indeed promotes earlier departures from the work place.

A study by Asgari and Jin (2018) tests whether regular and non-regular (occasional) remote workers compared to on-site workers use their schedule flexibility to postpone the start of their commute to miss the peak of congestion in the New York Metropolitan region. Using a hazard function model, they show that compared to on-site workers, teleworkers are more likely to commute in the less-crowded midday period instead of the morning peak time. A study by Lachapelle et al. (2018) analyzes the effect of different remote working arrangements on travel time and peak-period traffic using the 2005 Canadian General Social Survey. A special feature of this study is that it was measured directly, whether a person worked only remotely, only on-site or combined working remotely and on-site during the survey period. They find that working from home the whole workday is associated with a reduction of the overall travel time by on average 13 min. Generally, private motorized rush hour trips compared to mid-day trips are less likely for teleworkers. One exception to this is the morning peak-period journey taken by whole-day remote workers, which is not significantly avoided, mainly due to the need to transport children, e.g. to school, by a particular time of the day. The studies from the Seoul Metropolitan Area (Kim et al., 2015; Kim, 2017) also indicate that teleworkers more often avoid peak period travel and that their departure times are more dispersed on days they commute compared to office-based workers. The work from Sweden (Elldér, 2020) reveals that full-day remote workers are more likely to avoid rush-hour traffic in general compared to those who do not telework. In Switzerland, two pilot studies find that there is potential for flextime to reduce peak-period travel (Ecoplan, 2015; Weichbrodt et al., 2013); however, these are limited to some specific companies and restricted to specific geographical areas.

This literature review concludes that there is more recent evidence suggesting a complementary impact of telework on travel (e.g. Chakrabarti, 2018; Hu and He, 2016; Kim et al., 2015; Kim, 2017; Zhu, 2012; Zhu and Mason, 2014) rather than a substitution effect (e.g. Elldér, 2020; Mokhtarian et al., 2004). However, most studies agree that there is a positive impact of flexible working arrangements on traffic distribution throughout the day. Reduction effects of flexible working arrangements are often based on the simulation of different scenarios or theoretical modeling (see Hook et al., 2020) or limited samples (e.g. Mokhtarian et al., 2004; He, 2013). Moreover, many results regarding commuting behavior rely only on one-way distances, travel times, beeline distances or projections. However, people do not necessarily have only two commutes (e.g. some may drive home for lunch). Furthermore, it is only an assumption that people usually take the shortest route – for instance if a longer route is faster it may be more appealing. Therefore, actual commuting and travel distances derived from large scale data need to be analyzed. As systematic and representative research for Switzerland on this topic is scarce, this paper adds to the literature.

The theoretical framework of this paper follows a behavioral approach. It is assumed that travel behavior is an individual choice, which consists of different alternatives of which people select the alternative most beneficial for them (e.g. Domencich and McFadden, 1975; Salomon, 1985). There are various empirical applications following the behavioral framework to answer questions such as when travel will take place, which route is chosen, which mode of transport is preferred, and which determinants are relevant for these choices (e.g. Davidov et al., 2003; Domencich and McFadden, 1975; Franzen, 1997; Moore et al., 1984; Preisendörfer, 2000).

In many cases, commuting to work is a necessary component of gainful employment. However, commuting to work is usually unpaid, takes time, and can entail direct costs (such as costs for fuel or a public transportation ticket). Additionally, it comes along with opportunity costs, as the time used for commuting cannot be used for something else such as leisure. If the individual utility of gainful employment is optimized, it is expected that commuting to work will be reduced as much as possible. Moreover, as already explained, empirical research agrees that telework indeed reduces commuting. Hence, the first hypothesis of this study is that people who have the opportunity to do some of their work from home will take advantage of this and thus avoid commuting.

H1. Flexible working arrangements reduce the work-related distance traveled.

However, the commuting time saved could be used for other journeys. Furthermore, telework might eliminate the possibility of efficiently combining other activities with the commute. Thus, there is only an environmental benefit of remote work if the saved commute on home office days is not completely compensated by or even exceeded with trips for other purposes. This is especially important with regard to motorized private transport. Research has shown that remote workers tend to live further away from the workplace compared to on-site workers, which can outweigh the number of kilometers saved on office days (Hook et al., 2020). Moreover, many studies found a travel-inducing and complementary effect for non-work trips (e.g. Chakrabarti, 2018; Kim, 2017; Zhu and Mason, 2014), although some did not (e.g. Elldér, 2020; Mokhtarian et al., 2004). Because of these inconclusive results, the second research hypothesis is formulated to test the initial idea that flexible working arrangements could reduce traffic.

H2. Flexible working arrangements also reduce the total distance traveled (implying that there are no compensation effects in non-work travel).

Finally, a similar argument as that in H1 is made with regard to flextime. Although commuting may be inevitable for some people, they can still try to maximize the utility of their work route by minimizing travel time (Moore et al., 1984). When driving during peak time, congestion and traffic jams can entail stress, less comfort, or a higher mileage because of stop-and-go traffic. Moreover, the journey time is likely to be longer than if it occurred outside of rush hour. Additionally, empirical findings suggest that flextime and telework favor a more even distribution of traffic during the day (e.g. Asgari and Jin, 2018; Elldér, 2020; He, 2013). Although part-day remote work does not replace the commute, it at least allows the avoidance of peak period travel (Haddad et al., 2009; Lachapelle et al., 2018). Accordingly, it is hypothesized that people who have a flexible work schedule are more likely to commute outside of rush hour.

H3. Flexible working arrangements increase the likelihood of commuting outside of rush hour.

3. Data and methods

3.1. Data

The data used in this paper is the most recent available Swiss Mobility and Transport Microcensus (MTMC) from 2015 by the Swiss Federal Statistical Office and Swiss Federal Office for Spatial Development ARE (2017a). The MTMC is a micro-data trend survey on mobility behavior and attitudes of the Swiss population, which started in 1974 and is repeated every 5 years since then. Since 1994 it is conducted via Computer-assisted telephone interview (CATI) using a random sample of the Swiss resident population starting from age 6. In 2015, there was a response rate of 53% resulting in 57,900 interviews (Swiss Federal Statistical Office and Swiss Federal Office for Spatial Development ARE, 2017b). The data set contains detailed route recording of all ways traveled by a person on one specific target day. In addition, further relevant information about these routes – such as distance, duration, start and end place and time, mode of transportation, and purpose – is collected. Apart from this, the data set contains socio demographic and economic information about the respondents as well as various household characteristics. Although there is some information about the whole household, only one person out of each household is the target person whose traffic behavior is recorded. The target days are equally distributed throughout the whole year. Thus, the data are the best available source for testing the research hypotheses in Switzerland.

Besides these main data, which are conducted for each respondent, four additional modules covering supplementary topics were randomly assigned with different probabilities. For this study, the third module in particular is of great importance, as it contains questions about flexible forms work. The module was assigned to about 30% of respondents (Swiss Federal Statistical Office and Swiss Federal Office for Spatial Development ARE, 2017b). This means that not all working respondents received these questions about flexible working arrangements. However, since all modules were assigned randomly, missing values concerning telework and flextime are completely at random. Therefore, the results are unbiased. Since regular working and commuting practices are of interest here, all analyses are carried out for people who are gainfully employed (not in training), aged between 18 and 65 years, because the latter is the regular retirement age for males in Switzerland. Moreover, only routes traveled within the country are taken into account. Hence, the sample size drops considerably to about 8700 observations (see Fig. S1 in supplementary material). Descriptive results are weighted using the weighting coefficient provided in the data set.

3.2. Independent variables – telework and flextime

This paper focuses on two flexible working arrangements, which could help to relieve traffic. In the MTMC, respondents had been asked if they are able to do some of their work from home, which is a specific form of telework. Respondents, who answered this question with “yes”, or “sometimes”, were then asked to what extent (in % of full-time-equivalent). Since some of them choose not to work from home, a variable was built that represents actual telework usage. That is to say, the MTMC only records whether a person generally teleworks (e.g. working remotely 20% of the working time), while there is no information whether an individual actually teleworked on the target day. Therefore, group comparisons of teleworkers compared to those who never telework are carried out at the macro level. Since the questionnaire explicitly asks about working from home (and not from other places like a café or a train), the MTMC captures a specific kind of the telework; hence, these two terms will be used interchangeably. In the following, people who always work remotely (100% of their workload) are called full-time teleworkers, while the mixture between working from home and on-site during the workweek is designated as hybrid work.

The second form of flexible working arrangements considered is flextime. Respondents had been asked to what extent they can organize their own working time. The four answering categories in 2015 were the following: predetermined start and end time of working hours, predetermined core time, fixed number of working hours per week or month, and completely flexible working hours. Since even core work time could have a positive impact on traffic, flextime will be dichotomized into non-flexible (the first category), and flexible, that is collapsing the other three categories. See Table S1 in the supplementary material for descriptive information about all variables used in this study as well as an overview of how they were constructed.

3.3. Dependent variables – travel behavior

To test hypotheses 1 to 3, eight travel-related dependent variables are used. In the MTMC, every recorded route is assigned to a (main) purpose, such as work, shopping, use of services, business activity, leisure activity, or accompanying trips.[1] Based on this classification, there will be three kinds of travel: the commute, everything except the commute – referred to as non-work-travel, and the total travel, which is the sum of both. For each travel indicator the number of kilometers traveled via all routes, with the corresponding purpose, are totaled to record the overall distance traveled. It should be noted that individuals who did not commute or drive at the target day, still are included in the analyses with a value of zero. This is particularly important since these zero values are meaningful and represent special travel patterns. For instance, zero kilometers commuted are observed when a person only worked remotely on the target day. Zero non-work travel can occur if somebody only commuted or did not leave the house at all. Finally, zero kilometers driven by motorized private transport can indicate that an individual only covered distances by walking, cycling or using public transport. Hence, these data they do not rely on any prior travel-related assumptions, which generates a precise measure of the actual distances traveled. This approach is reasonable as it also depicts specific travel patterns. E.g., people do not necessarily take only one trip to and from work. Some might drive home for lunch, which would result in more kilometers commuted. Only considering one-way commuting distances would lead to a distorted picture in this case. Another benefit is that this approach also captures trip chaining adequately. Each individual outbound trip of a chained journey is labeled with the purpose of the activity at the destination. The final part of a chained journey is the return trip. This way home is labeled with the purpose of the main activity, i.e., the activity that took up the most time. Hence, chaining the commute with other trips usually results in a smaller distance covered for the work route, since the purpose of travel is split between work and non-work. Such cases could hardly be captured by any other approach. In conclusion, considering actual behavior, that is how much had been traveled for what reasons, is most suitable to test the impact of flexible working arrangements on traffic.

Additionally to the distances, the main mode of transport is recoded for every trip. Motorized private transport (MPT), namely driving with own car or motorcycle, is the most energy-consuming mode of transportation. Therefore, a reduction of travel by MTP is needed in order to observe any beneficial impact of telework on the environment. Hence, the total distances traveled by MPT are additionally presented for all three types of travel. Accordingly, the total distances traveled with all modes are called person kilometers traveled (PKT), and distances covered with motorized private transport are referred to as vehicle kilometers traveled (VKT).

Finally, two dummy variables are constructed for commuting by MPT during morning and evening peak time respectively. Here, the

[1] In the MTMC, all trips (outbound and return) are assigned to a purpose. The purpose for any outbound trip is based on the activity at the destination. The assignment of purposes to ways home is based on the purpose of the previous activities. In the simplest case of only two ways, the trip home is assigned to the same purpose as the outbound trip.

dummy variable approach is suitable for evaluating whether people use their flexibility to drive outside the peak period, because it has the advantage of considering all work routes taken by a single person. Additionally, it is possible to investigate morning rush hour commuting separately from the evening rush hour commute, which had previously been found to be an important distinction (Lachapelle et al., 2018). The rush-hour dummy variable is coded as 1 if at least one journey commuted by MPT starts and/or ends between 7:15 a.m. to 8:15 a.m. for the morning peak period or between 5 p.m. to 6:30 p.m. for the evening rush hour (cf. Swiss FEDRO - Federal Roads Office, 2020). There are almost 2400 people who actually commuted via MPT on the target day for whom information on flexible working arrangements is available.

3.4. Control variables

Three main types of variables are considered as control variables for hypothesis testing: sociodemographic and economic, mobility-related, and job-related variables. These variables are of theoretical interest, available in the MTMC and have been found to be important in other studies investigating travel patterns and flexible working arrangements (e.g. Elldér, 2020; He, 2013; Moore et al., 1984; Ravalet and Rérat, 2019; Walls et al., 2007; Zhu, 2012; Zhu and Mason, 2014). Accordingly, age, gender, education, income, and type of household (family status and children), and nature of residential area (city, agglomeration, rural area) are included. Considering travel behaviors as decisions, different mobility-related factors can offer opportunities or impose restrictions regarding the travel choices. Hence, vehicle accessibility and the holding of public transport subscriptions are taken into consideration. Finally, the following characteristics of job and workplace are also taken into account: being employed vs. self-employed, working full-time or part-time, job classification (International Standard Classification of Occupations (ISCO)), and nature of workplace area. When testing H1 to H3, the day of the week is also controlled for in order to catch common differences between weekdays and weekends.

3.5. Statistical models

The research hypotheses are tested by comparing the groups of teleworkers vs. on-site workers in multivariate regression models. OLS regression models on the distances traveled are calculated applying robust standard errors to test H1 and H2. Telework and flextime are included in all regression models simultaneously in order to isolate their effects on the different travel indicators (Allen et al., 2015: 61). As has been done in other studies (e.g. Elldér, 2020; Hu and He, 2016; Zhu, 2012), and because the distances are right skewed, they are logged.[2] Therefore, the OLS regression coefficients (β) are interpreted as percentage changes in the travel indicators using this calculation: (exp(β) – 1) * 100%. For every kind of travel, there are separate regression models analyzing PKT and VKT respectively.[3] The total distance commuted on the target day is the dependent travel behavior used to test H1. As in other studies (e.g. Asgari and Jin, 2018; Zhu, 2012) people who always work from home represent a special case, because they do not have a commuting distance per definition. Therefore, these full-time teleworkers will be excluded from the analyses testing H1 (commuting behavior). However, since this type of workplace condition is important for the total travel behavior working full-time from home is included as a specific type of telework when testing H2. H2, addressing possible rebound effects, is tested in two steps. First, the impact of flexible working arrangements on non-work traffic is calculated to identify potential induced travel. Since the main question is whether enough people reduce travel based on telework to be reflected in the aggregate (Mokhtarian, 1991b), the impact of flexible working arrangements on the total distance traveled is calculated as a second step. Finally, to test H3, all commutes on the target day are evaluated with regard to the time at which they took place. For this, two logistic regression analyses are applied, for the morning and evening commutes respectively. In order to be able to estimate the influence of flexible working arrangements on the different mobility behaviors in as unbiased a way as possible, the previously described control variables are taken into account in all regression models. In the course of this, variance inflation factors (VIFs) were calculated to test for multicollinearity among the independent variables. The mean VIF is 1.9, which is reasonable; and no single VIF is noticeably large.

4. Results

The majority of participants in the labor market cannot telework in Switzerland (68%). Of workers, who could work from home, 11.3% decide to not take up this option. Full-time teleworkers working solely from home make up only 2.5% of all respondents. The most common form of telework is hybrid work: 26.2% of all workers combine working from the workplace with working from home during the workweek. Altogether, 28.7% actually work from home, while 71.3% do not work remotely at all. Non-flexible working – i.e. start and finish times are predetermined – is, with 41.5%, the most common type of work schedules in Switzerland. Predetermined core time offers more flexibility and is used by 15.9% of employed respondents. Even more people (18.4%) have only a contractually agreed number of working hours per week or month, but can decide for themselves when they want to work. Finally, 24.3% of the respondents have completely flexible working hours, which means they can fully decide on their working timings and number of hours. Thus, almost three fifths of the respondents can at least to some extent decide their own working hours, and about two fifth of the people in the data set do not have any flexibility over their schedule. In conclusion, there is a bigger share of temporal flexibility than in terms of spatial flexibility for jobs in Switzerland.

On average, workers cover a total distance of 45.6 km per day. This distance is made up of an average of 15 km for commuting and 30.6 km of trips for other purposes. The larger share of non-work travel also highlights the importance of considering effects of flexible working arrangements on non-work travel. The data shows that 35% of labor market participants commute during the morning rush hour, while 43% drive during evening peak periods.

4.1. Flexible working arrangements and distances traveled

Table 1 presents the results of OLS regression models on the distance traveled for work (a), for purposes other than work (b), as well as for the total distance covered (c). The left side of each travel indicator shows estimates of distance covered with all modes of transport (PKT), whereas the right side depicts distance driven by motorized private transport (VKT). First, as expected, hybrid work is statistically significant associated with less kilometers commuted. Model 1 shows that hybrid workers commute on average 21% less with all modes of transport compared to on-site workers (coefficient = −0.235). Remote workers also commute 14.6% less by motorized private transport (Model 2, coefficient = −0.158). However, there is no statistically significant effect of flextime on the distance commuted.

Less time spent commuting offers more free time to travel for other reasons such as leisure or shopping. Indeed, hybrid workers travel 21.5% more for non-work purposes (Model 3, coefficient = 0.195), and

[2] There are people, who did not commute or travel on the target day, thus, having zero PKT/VKT. It is of great importance to consider these cases when transforming the dependent variables. For this purpose, 1 km is added to each distance, and the variable is logged afterwards. Since the natural logarithm of 1 equals 0, the new transformed variable still represents individuals, who did not travel, adequately with a value of zero.

[3] Additionally, as a robustness check, tobit regression models were calculated to account for censoring at zero kilometers. Since the conclusions are the same as for the OLS regression models, these results are not presented.

Table 1
OLS regression on logged distances traveled.

	(a) Commute		(b) Non-work travel		(c) Total travel	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	PKT	VKT	PKT	VKT	PKT	VKT
Flexible working arrangements						
Hybrid work (i.e. part-time telework) (ref. = on-site work)	−0.235***	−0.158***	0.195***	0.151**	−0.001	0.015
Full-time telework (ref. = on-site work)			0.149	−0.022	−0.374**	−0.464**
Flextime (ref. = no flextime)	0.002	−0.035	0.121**	0.065	0.091*	0.0288
Full-time work (ref. = part-time work)	0.399***	0.306***	−0.270***	−0.199***	0.042	0.045
Employed (ref. = self-employed)	0.256***	0.148*	−0.123	−0.150*	0.091	−0.004
Women (ref. = men)	−0.236***	−0.112**	−0.065	−0.127*	−0.209***	−0.171***
Age	−0.003	−0.002	−0.009***	−0.008***	−0.008***	−0.007***
Income (in thousand CHF)	0.027**	0.031***	0.036***	0.042***	0.039***	0.050***
Year of education	0.004	−0.016*	−0.016	−0.024**	−0.001	−0.021*
Type of household (ref. = single person)						
Couple	0.052	0.033	−0.169**	−0.124	−0.075	−0.036
Couple with child(ren)	0.103	0.104*	−0.128*	−0.004	0.032	0.099
Single-parent with child(ren)	0.122*	0.139	−0.051	0.159	0.023	0.219*
Other (e.g. shared flat)	0.165	0.033	0.049	0.049	0.129	0.101
Area of home (ref. = rural community)						
Agglomeration	−0.112*	−0.145**	0.030	−0.108	−0.146**	−0.211***
City	−0.192**	−0.280***	−0.131*	−0.359***	−0.286***	−0.507***
Area of workplace (ref. = rural community)						
Agglomeration	0.082	0.048	0.029	0.058	0.076	0.074
City	0.034	−0.187**	−0.096	−0.110	0.003	−0.194**
Car availability (ref. = no car)						
Always	0.144	0.494***	0.377***	0.884***	0.287**	1.148***
By prior arrangement	−0.058	0.051	0.169	0.359**	0.065	0.360***
Public transport subscription	0.123**	−0.362***	−0.021	−0.339***	0.123***	−0.500***
Weekend (ref. = weekdays)	−1.731***	−1.217***	0.532***	0.447***	−0.407***	−0.235***
Constant	1.728***	1.396***	2.511***	1.831***	3.207***	2.318***
Number of observations	6587	6587	6767	6767	6767	6767
R^2	0.266	0.209	0.046	0.075	0.065	0.124

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. PKT = Person kilometers traveled by all modes of transport. VKT = Vehicle kilometers traveled by motorized private transport. All models controlled for the type of occupation (ISCO; results not presented). Coefficient's (β) interpretation in percentage-changes: (exp(β) – 1) * 100%.

they have 16.3% higher VKT driven by motorized private transport (Model 4, coefficient = 0.151) compared to individuals who never telework. Hence, a rebound effect of part-time remote work on non-work travel can be observed. Interestingly, people who always work from home do not significantly differ from on-site workers in the amount of non-work travel. Flextime workers cover 12.9% greater distances by all modes of transport compared to non-flextime workers (Model 3, coefficient = 0.121). However, they do not have statistically significantly more VKT (Model 4).

The total distances traveled show that hybrid workers do not differ statistically significantly from individuals, who always work on-site (Models 5 and 6). Accordingly, saved commutes are offset with non-work journeys resulting in a zero impact of occasional telework on travel behavior overall. In comparison, people who always work from home travel for non-work purposes as much as those who never telework (Models 3 and 4). Since full-time teleworkers do not have to commute, their total distances result in fewer PKT and VKT compared to on-site workers (Models 5 and 6). Interestingly, they drive even less by car or motorcycle (Model 6, −37.1%, coefficient = −0.464) than they travel less with all modes of transport (Model 5, −31.2%, coefficient = −0.374). Flextime does not statistically significantly affect the VKT (Model 6).

Furthermore, full-time workers as compared to part-time workers have more work-related travel on the one hand, but less non-work travel on the other hand. However, there are no differences regarding the total distances traveled. This can probably be attributed to the fact that full-time workers have more time restrictions due to their job. In addition, people living or working in cities, as compared to rural areas, drive less on average, which could be explained by the fact that in cities the distances that need to be covered to fulfill different needs such as work, shopping, and leisure, are shorter. Moreover, owners of a public transport subscription generally drive less by motorized private transport compared to individuals who do not own a subscription (Models 2, 4, and 6). However, one could argue that people's decision to purchase a public transport subscription could be based on their teleworking practices, which could in turn be related to their travel behavior. To ensure that none of the key findings was biased by the inclusion of public transport subscription, all six models were run without this variable as a robustness check. Neither the main results of the models nor the significance tests changed substantially. All previously presented conclusions remained unchanged. Finally, as expected, individuals commute less on weekends, but travel more for non-work purposes. In total, they drive on average 20.9% less on weekends (Model 6, coefficient = −0.235).

4.2. Flexible working arrangements and congestion relief

Finally, H3 assumes that flexible working arrangements can help to reduce congestion. Table 2 displays the results of two logistic regression models analyzing the effect of flexible working arrangements on rush hour commuting. The coefficients presented are odds ratios. Hence, 1 indicates no effect, while an odds ratio bigger (smaller) than 1 represents a positive (negative) impact. First of all, differentiating between morning and evening peak time offers different insights. Contrary to the assumption, the data suggests that flextime workers are more likely to commute during morning peak time compared to non-flexible workers (odds ratio = 1.3). No difference is found between hybrid workers compared to on-site workers for the morning commute. Nevertheless, in line with H3, hybrid workers are less likely to drive during evening peak time (odds ratio = 0.7). There is no statistically significant effect of flextime on evening peak period travel. Furthermore, full-time workers are more likely to commute during the evening commute compared to part-time workers, probably because the latter can finish work before the evening rush hour. Moreover, it shows that single parents are more likely to commute during the morning rush hour. This could indicate

Table 2
Logistic regression on commuting during morning and evening rush hour respectively by motorized private transport (i.e. car or motorcycle).

	Morning rush hour commute	Evening rush hour commute
Flexible working arrangements		
Flextime (ref. = no flextime)	1.298**	1.149
Hybrid work (i.e. part-time telework) (ref. = on-site work)	1.148	0.702**
Full-time work (ref. = part-time work)	0.947	1.549***
Employed (ref. = self-employed)	0.917	1.234
Women (ref. = men)	1.561***	1.149
Age	0.991*	0.999
Income	1.030	0.965
Year of education	1.055**	0.982
Type of household (ref. = single person)		
Couple	1.118	1.003
Couple with child(ren)	1.289	1.075
Single-parent with child(ren)	1.698*	1.201
Other (e.g. shared flat)	1.076	1.043
Residential area of home (ref. = rural community)		
Agglomeration	0.902	0.990
City	0.736*	0.715**
Residential area of workplace (ref. = rural community)		
Agglomeration	1.211	0.843
City	1.105	0.858
Weekend (ref. =weekdays)	0.603*	0.3999***
Number of observations	2367	2367

Note: Coefficients = odds ratios. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. All models controlled for the type of occupation (ISCO; results not presented).

that they combine taking children to (pre)school with their commute, which is in line with the findings of Lachapelle et al. (2018).

5. Summary and discussion

The aim of this study is to investigate the potential of the digitalization of the labor market for reductions in traffic and congestion relief. Teleworkers are still in the minority with a share of less than 30%. Most of them are hybrid workers, i.e. mix working from the workplace and from home, and only a small minority always works from home. Interestingly, 11% of respondents who have the possibility to work from home some of the time, are not using this option. According to the MTMC flextime is quite common in Switzerland, offering temporal flexibility to three fifths of the Swiss workers. Three hypotheses concerning the impact of flexible working arrangements on different aspects of commuting and general travel behavior are empirically tested using the most recent nationwide micro level transport data (MTMC) from 2015 in Switzerland.

Research hypothesis H1 assumes that flexible working arrangements cause a reduction in work-related mobility behavior. The empirical results show that hybrid work is associated with fewer kilometers being commuted by both all modes of transport and motorized private transport. This can be due to three reasons: First, some respondents are actually working a whole workday from home, and thus, fully replace the commute. Second, some workers typically drive home for lunch and return to the workplace afterwards, so that even half-day home office has a travel reducing effect. Third, people are efficiently chaining the journey to work with trips for other purposes. There is no statistically significant effect of flextime. Overall, hypothesis 1 is partly supported, at least with respect to telework.

Hypothesis H2 postulates a reduction in total mobility. The empirical results show that hybrid work is associated with larger distances of non-work-related travel. This is in line with most research finding a complementary effect of telework. However, the commute is not over-compensated for, since the results show a non-significant impact on total travel. So in this study, less commuting and more non-work travel add up to a neutral impact of hybrid work on total mobility. This is in contrast to the other studies, which found a complementary effect of telework (e.g. Chakrabarti, 2018; de Vos et al., 2018; Kim et al., 2015; Zhu and Mason, 2014), and also differs from work finding a travel reduction (Elldér, 2020). Because this is a cross-sectional study, it cannot be assessed, whether there is unobserved heterogeneity. It could be that hybrid workers make more non-work trips because they are generally more active people. After all, telework offers time slots to travel to leisure activities. The distinction between people always working from home and doing hybrid work turned out to be particularly important. Although statistically significant effects of full-time remote working on overall travel had been found, this is not true for the more common hybrid work. Altogether, H2 needs to be rejected. The results suggest that the occasional usage of flexible working arrangements does not lead to a reduction in traffic.

The third hypothesis, assuming a more even distribution of traffic through flexible working arrangements, gains two interesting insights. First, it is useful to distinguish between morning and evening rush hours. Second, evidence on the effect on flexible working arrangements is mixed. Surprisingly, flextime workers are even more likely to depart during morning rush hour. An explanation for this could be that people who can work flexibly care less when exactly they arrive, and thus they may not mind encountering traffic in the morning. However, teleworkers are less likely to travel during evening peak-time. An explanation could be that people tend to work remotely in the morning or for half a day. This is also in line with most people in Switzerland only executing a small part of their workload from home. Hence, even if they commuted to work on that day, they would still be able to avoid traveling during the evening rush hour. Another possibility could be that they chain their commute with trips for other purposes, which is usually more efficient than doing these trips separately. Overall, H3 is partly supported, suggesting that only telework could affect evening traffic.

In summary, this study shows that the provision of flexible working arrangements by itself does not lead to a reduction in traffic, and if at all, there is only small potential for traffic redistribution. The strength of this study is that it uses a behavioral approach that is based on the most recent nation-wide data for Switzerland considering actual distances traveled. Therefore, it is particularly reliable compared to studies using one-way distances, air-line distances or travel times. Furthermore, this work presents a comprehensive picture of the overall effect of telework because it does not exclude specific groups of people such as part-time workers or self-employed individuals. This study is also particularly useful in showing connections between commutes and non-work trips and how these lead to a neutral impact of telework on the total distance traveled. Moreover, this research isolates the impact of remote work from effects of flextime. In addition, this work shows the benefits of a separate consideration of morning and evening commutes to study the effect of flexible working arrangements. However, this study also has a number of limitations and raises questions for further research. One issue concerns the data itself, because flexible working arrangements were only surveyed for a random subsample of 30% of all respondents. Additionally, only a general indicator for telework could be used instead of a direct measure that captures the actual usage of remote work on the target day. While this general indicator provides interesting insights into the macro level impact of telework on travel, it also leaves some questions unanswered. In particular, the general indicator cannot show differences in the teleworking practices on a working day, while the direct measure allows to distinguish workers who telework the complete day from workers who combine working remotely and on-site on one workday. These two teleworking practices could have different effects on travel behavior as work from Sweden shows (Elldér, 2020). Thus, understanding these practices and their macro level consequences is an important subject for future research. Furthermore, a direct telework indicator would make it possible to separate not being at the workplace due to sickness or vacation from remote work. This could be illuminative

as these reasons might lead to different travel behavior as well. Data from the MTMC showed that not all people who could work from home, actually do so. The same could be true for flextime offers, whose usage had not been recorded in the MTMC. In addition, this study is not able to evaluate effects of flexible working arrangements on traffic that arise over the course of a longer period of time, because only one day was surveyed. This could be important, because trips forgone on home-based days could be caught up during the working week, as work in Great Britain by de Abreu e Silva and Melo (2018) demonstrates. Their study also highlights different outcomes for single and two worker households, which could not be considered in this paper. Since this paper already finds induced non-work travel for teleworking individuals, considering the household's travel could even show an increase of the total distances covered, as other work shows (e.g. Kim, 2017).

Further empirical micro level research is advised, explicitly distinguishing between the possibility and utilization of flexible working arrangements. A subsample of about 2100 people in the MTMC was asked how often they experience traffic jams on their way to work and what they do if they run into congestion on their commutes. Only about 40% of the respondents faced congestion at least once a month. The most common strategy for dealing with it was to do nothing but schedule in time for the congestion (36%). Thirty-one percent simply chose another, probably less crowded, route. In the end, there are 22% that state they would depart earlier or later, which indicates at least some willingness to use flextime in order to avoid congestion. This highlights that (theoretically promising) measures will only be successful, first, if people see a problem that needs to be addressed, and second, if they contribute by actually using opportunities for flexibility.

Finally, there have been fewer traffic jams in 2020 compared to 2019 (−34%, Swiss Federal Statistical Office and Swiss Federal Roads Office FEDRO, 2021) in Switzerland, probably driven by the imposed obligation to work from home due to the coronavirus pandemic. To what extent this will lead to a lasting increase in the spread of flexible working arrangements and whether the altered travel behavior due to home-based working and lockdowns is beneficial for traffic reduction needs to be investigated in future studies.

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Declaration of Competing Interest

None.

Appendix A. Supplementary data

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References

de Abreu e Silva, J., Melo, P.C., 2018. Does home-based telework reduce household total travel? A path analysis using single and two worker British households. J. Transp. Geogr. 73, 148–162. https://doi.org/10.1016/j.jtrangeo.2018.10.009.

Allen, T.D., Golden, T.D., Shockley, K.M., 2015. How effective is telecommuting? Assessing the status of our scientific findings. Psychol. Sci. Public Interest 16 (2), 40–68. https://doi.org/10.1177/1529100615593273.

Andreev, P., Salomon, I., Pliskin, N., 2010. Review: state of teleactivities. Transp. Res. C 18, 3–20.

Asgari, H., Jin, X., 2018. An evaluation of part-day telecommute impacts on work trip departure times. Travel Behav. Soc. 12, 84–92. https://doi.org/10.1016/j.tbs.2017.04.002.

Black, W.R., 2001. An unpopular essay on transportation. J. Transp. Geogr. 9, 1–11.

Chakrabarti, S., 2018. Does telecommuting promote sustainable travel and physical activity? J. Transp. Health 9, 19–33.

Davidov, Eldad, Schmidt, Peter, Bamberg, Sebastian, 2003. Time and money: an empirical explanation of behaviour in the context of travel-mode choice with the German microcensus. Eur. Sociol. Rev. 19 (3), 267–280.

Domencich, T.A., McFadden, D., 1975. Urban travel demand. In: A Behavioral Analysis. North-Holland, Amsterdam.

Ecoplan, 2015. Verkehrsinfrastrukturen smarter nutzen dank flexibler Arbeitsformen. Entlastungspotentiale für die Hauptverkehrszeiten am Beispiel der Region Bern, Bern. https://www.ecoplan.ch/de/projekte.

Elldér, E., 2020. Telework and daily travel: new evidence from Sweden. J. Transp. Geogr. 86, 102777 https://doi.org/10.1016/j.jtrangeo.2020.102777.

Franzen, A., 1997. Umweltbewusstsein und Verkehrsverhalten: Empirische Analysen zur Verkehrsmittelwahl und der Akzeptanz umweltpolitischer Massnahmen. Rüegger Verlag, Zürich.

Haddad, H., Lyons, G., Chatterjee, K., 2009. An examination of determinants influencing the desire for and frequency of part-day and whole-day homeworking. J. Transp. Geogr. 17, 124–133.

He, S.Y., 2013. Does flexitime affect choice of departure time for morning home-based commuting trips? Evidence from two regions in California. Transp. Policy 25, 210–221. https://doi.org/10.1016/j.tranpol.2012.11.003.

Hook, A., Court, V., Sovacool, B.K., Sorrell, S., 2020. A systematic review of the energy and climate impacts of teleworking. Environ. Res. Lett. 15, 093003.

Hu, L., He, S., 2016. Association between telecommuting and household travel in the Chicago metropolitan area. J. Urban Plan. Dev. 142 (3), 04016005.

Keller, M., 2019. Staukosten Schweiz 2015. Swiss Federal Office for Spatial Development ARE, Bern. https://www.are.admin.ch/are/de/home/medien-und-publikationen/publikationen/verkehr/staukosten-schweiz-2015-schlussbericht.html.

Kim, S.-N., 2017. Is telecommuting sustainable? An alternative approach to estimating the impact of home-based telecommuting on household travel. Int. J. Sustain. Transp. 11 (2), 72–85.

Kim, S.-N., Choo, S., Mokhtarian, P.L., 2015. Home-based telecommuting and intra-household interactions in work and non-work travel: a seemingly unrelated censored regression approach. Transp. Res. A 80, 197–214.

Lachapelle, U., Tanguay, G.A., Neumark-Gaudet, L., 2018. Telecommuting and sustainable travel: reduction of overall travel time, increases in non-motorised travel and congestion relief? Urban Stud. 55, 2226–2244.

Lane, B.W., 2019. Revisiting 'an unpopular essay on transportation:' the outcomes of old myths and the implications of new technologies for the sustainability of transport. J. Transp. Geogr. 81, 102535 https://doi.org/10.1016/j.jtrangeo.2019.102535.

Lyons, G., Haddad, H., 2008. Commute replacement and commute displacement the rise of part-day home working. Transp. Res. Rec. 2082, 1–7. https://doi.org/10.3141/2082-01.

Meissner, J.O., Weichbrodt, J., Hübscher, B., Baumann, S., Klotz, U., Pekruhl, U., Gisin, L., Gisler, A., 2016. Flexible neue Arbeitswelt. In: Eine Bestandsaufnahme auf gesellschaftlicher und volkswirtschaftlicher Ebene. vdf Hochschulverlag AG an der ETH-Zürich, Zürich. https://doi.org/10.3929/ethz-a-010659566.

Mokhtarian, P., 1991a. Defining telecommuting. Transp. Res. Rec. 1305, 273–281.

Mokhtarian, P., 1991b. Telecommuting and travel: state of the practice, state of the art. Transportation 18 (4), 319–342.

Mokhtarian, P.L., Collantes, G.O., Gertz, C., 2004. Telecommuting, residential location, and commute-distance traveled: evidence from state of California employees. Environ. Plan. A 36, 1877–1897.

Moore, A.J., Jovanis, P.P., Koppelman, F.S., 1984. Modeling the choice of work schedule with flexible work hours. Transp. Sci. 18, 141–164. http://www.jstor.org/stable/25768126.

Perch-Nielsen, S., von Felten, N., Henzen, C., Meissner, J., Sprenger, M., Bieri, M., Arvanitis, S., Seliger, F., Ley, M., 2014. Auswirkungen neuer Arbeitsformen auf den Energieverbrauch und das Mobilitätsverhalten von Arbeitnehmenden. KOF Stud. 48 https://doi.org/10.3929/ethz-a-010699193. Zürich.

Preisendörfer, P., 2000. Strukturell-situationale Gegebenheiten als Bestimmungsfaktoren der Verkehrsmittelwahl. Soz. Welt 51, 487–501.

Ravalet, E., Rérat, P., 2019. Teleworking: decreasing mobility or increasing tolerance of commuting distances? Built Environ. 45, 582–602. https://doi.org/10.2148/benv.45.4.582.

Salomon, I., 1985. Telecommunications and travel: substitution or modified mobility? J. Transp. Econ. Policy 19 (3), 219–235.

Salomon, I., 1986. Telecommunications and travel relationships: a review. Transp. Res. A 20 (3), 223–238.

Swiss Federal Council, 2021. Switzerland's long-term climate strategy. Bern. https://unfccc.int/documents/268092.

Swiss Federal Department of the Environment, Transport, Energy and Communications DETEC and Swiss Federal Roads Office FEDRO, 2018. Steigender Verkehr auf den Nationalstrassen. Faktenblatt, Bern, 17.1.2018.

Swiss Federal Office for Spatial Development ARE, 2016. Transport Outlook 2040 - Development of Passenger and Freight Transport in Switzerland. Swiss Federal Office for Spatial Development. Bern: 812.104.e.

Swiss Federal Office for the Environment FOEN, 2021. Greenhouse Gas Emissions in Switzerland. Development in CO2 Equivalents and Emissions by Sector. KL013, Bern. https://www.bafu.admin.ch/bafu/en/home/topics/climate/in-brief.html.

Swiss Federal Roads Office FEDRO, 2019. Roads and Traffic 2019 – Developments, Facts, Figures. Annual publication of the Federal Roads Office, Bern. https://www.astra.admin.ch/astra/en/home/documentation/facts-and-figures/archive.html.

Swiss Federal Statistical Office, 2021. Pendlermobilität in der Schweiz 2019 - Mit einer Vertiefung zur Länge der Arbeitswege. Neuchâtel. Swiss Federal Statistical Office. BFS-Nummer 1351–1900.

Swiss Federal Statistical Office and Swiss Federal Roads Office FEDRO, 2021. Stau: Staubelastung auf dem Nationalstrassennetz. Bern. Swiss Federal Statistical Office and Swiss Federal Roads Office FEDRO. BFS-Nummer gr-d-11.03.03-stau.

Swiss FEDRO - Federal Roads Office, 2020. Verkehrsentwicklung und Verkehrsfluss 2019 (V1.00). Bern. https://www.astra.admin.ch/astra/de/home/themen/nationalstrassen/verkehrsfluss-stauaufkommen/verkehrsfluss-nationalstrassen.html.

Swiss FSO - Federal Statistical Office, 2020. Bruttowertschöpfung nach Branchen. https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/wohlfahrtsmessung/gueter/oekonomische-gueter/branchenstruktur.assetdetail.14447498.html.

Swiss FSO - Federal Statistical Office and Swiss ARE - Federal Office for Spatial Development, 2017a. Dataset: Mobility and Transport Microcensus 2015. Data request via. https://www.are.admin.ch/are/de/home/mobilitaet/grundlagen-und-daten/mzmv/datenzugang.html.

Swiss FSO - Federal Statistical Office and Swiss ARE - Federal Office for Spatial Development, 2017b. Verkehrsverhalten der Bevölkerung. Ergebnisse des Mikrozensus Mobilität und Verkehr 2015. Neuchâtel and Bern: BFS-Nummer 840–1500.

de Vos, D., Meijers, E., van Ham, M., 2018. Working from home and the willingness to accept a longer commute. Ann. Reg. Sci. 61, 375–398.

United Nations Framework Convention on Climate Change UNFCCC, 2015. Adoption of the Paris Agreement Report No. FCCC/CP/2015/L9/Rev.1. United Nations Framework Convention on Climate Change.

Walls, M., Safirova, E., 2004. A Review of the Literature on Telecommuting and Its Implications for Vehicle Travel and Emissions. Research Papers in Economics, Discussion Paper 04–44, pp. 1–23.

Walls, M., Safirova, E., Jiang, Y., 2007. What drives telecommuting? Relative impact of worker demographics, employer characteristics, and job types. Transp. Res. Rec. 111–120 https://doi.org/10.3141/2010-13.

Weichbrodt, J., Sprenger, M., Steffen, M.H., Tanner, A., Meissner, J.O., Schulze, H., 2013. WorkAnywhere. In: SBB AG und Swisscom AG (Ed.), Mehr Produktivität und Zufriedenheit der Mitarbeitenden sowie Entlastung der Verkehrsinfrastruktur dank mobil-flexibler Arbeitsformen. https://irf.fhnw.ch/handle/11654/4994.

Zhu, P., 2012. Are telecommuting and personal travel complements or substitutes? Ann. Reg. Sci. 48, 619–639. https://doi.org/10.1007/s00168-011-0460-6.

Zhu, P., 2013. Telecommuting, household commute and location choice. Urban Stud. 50, 2241–2459.

Zhu, P., Mason, S.G., 2014. The impact of telecommuting on personal vehicle usage and environmental sustainability. Int. J. Environ. Sci. Technol. 11, 2185–2200. https://doi.org/10.1007/s13762-014-0556-5.