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Estimating post-pandemic effects of working from home and teleconferencing on travel behaviour

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Like in many other countries, the Dutch government instructed people to work from home where possible during the COVID-19 pandemic to halt the transmission of the virus. This policy seems to have resulted in a structural increase in working from home and teleconferencing that will outlast the pandemic. However, the longer-term effects on travel behaviour are still unclear. Making use of panel data collected using the Netherlands Mobility Panel, this paper has two main aims. First, it analyses developments in working from home and teleconferencing since COVID-19. Second, it estimates the expected post-pandemic effects on travel behaviour. The results show that compared to before the pandemic, the average number of hours that people work from home has doubled and roughly two-thirds of respondents indicate that they teleconference more often. We estimate that structural, post-pandemic increases in working from home and teleconferencing will result in a negative effect on distances travelled by train (-3% to -9%), by bus, tram, and metro (-1% to -5%) and car (-1 to -5%). The estimated effect on the distance travelled by bicycle (-2% to 0%), and walking (0% to +1%) is smaller or even positive, due to people making more complementary trips for other purposes when working from

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home. When interpreting these results, we should keep in mind that due to various other factors, such as population growth, total travel demand will still grow in the near future.

Keywords: *COVID-19; Travel Behaviour; Teleconferencing; Working from Home.*

1. Introduction

During the years 2020 through 2022, governments worldwide took measures to stop the spread of the novel coronavirus SARS-COV-2 (Brauner et al., 2020; Haug et al., 2020). Many governments advised, urged, or compelled people to work from home where possible (Brauner et al., 2020). Suddenly, many employees and employers were forced to experiment with working from home during the pandemic. As a result, use of telecommunication software and especially teleconferencing rose sharply. Simultaneously, the levels of congestion and of peak-travel crowding in public transport decreased substantially (Beck & Hensher, 2020a; de Haas et al., 2020).

The instruction to work from home as much as possible was an important measure during the pandemic in The Netherlands as well. Based on measurements using the Netherlands Mobility Panel (MPN; Hoogendoorn-Lanser et al. 2015), we observed a substantial increase in working from home and teleconferencing after implementation of these measures, especially in the first months of the COVID-19 pandemic (Hamersma et al., 2021). The total number of trips and distance travelled in the Netherlands reduced by 55% and 68% respectively at the beginning of the pandemic when compared to the fall of 2019 and the use of public transport was affected the most with a decrease of over 90% of trips (de Haas et al., 2020).

These substantial initial effects raise the question to what extent working from home and teleconferencing will affect travel behaviour after the pandemic is over. These structural effects of working from home on travel behaviour can be juxtaposed with the temporary effects of working from home on travel behaviour that occurred during the pandemic. These temporary effects will only turn structural when people decide to work from home more often than they did before the pandemic, even if there are no longer any temporary reasons directing them to do so, such as COVID-19 infections or work-from-home directives.

As of the year 2023, it seems evident that an increase in working from home and teleconferencing will be a structural change in the post-pandemic world (see for example, Beck et al., 2020; Beck & Hensher, 2020b; de Haas et al., 2020; Jain et al., 2022; Olde Kalter et al., 2021). This change will likely affect post-pandemic travel behaviour, which could potentially have consequences for the accessibility and sustainability of the transport system (van Wee & Witlox, 2021), where we define accessibility as the extent to which people are able to access destinations to participate in activities or exchange goods (Miller, 2018) and for sustainability we follow the narrow, environmental definition given in Zhao et al. (2020), which mostly refers to reducing both unwanted emissions and the use of depletable materials.

There is comparatively less in-depth information in the literature on the size of the expected structural, post-pandemic, effects of working from home and teleconferencing on travel behaviour. Studies show that there probably will be a negative structural effect on commuting travel (Beck & Hensher, 2022; Currie et al., 2021), that there might be a positive structural effect on leisure and maintenance travel (Balbontin et al., 2022; Chen & Steiner, 2022), and that the negative net effect is likely to be strongest for public transport (Ceccato et al., 2022; Gkiotsalitis & Cats, 2021; Ton et al., 2022).

The main contribution of this paper then is to provide estimates of the size of the post-pandemic effect of working from home and teleconferencing on travel behaviour for all main modes of personal travel. To present these estimates, this paper will provide the answer to two questions that will guide our analyses:

- What will the structural, post-pandemic increase in working from home and teleconferencing be?
- What effects will these increases have on post-pandemic travel behaviour?

As a result, we will first present developments in working from home and teleconferencing since the start of the pandemic and the expected structural change after the pandemic is over. Then, we will calculate the effects of these changes on travel behaviour in the Netherlands. These results will be based on quantitative analyses of data collected with the Netherlands Mobility Panel (MPN) and the National Travel Survey of the Netherlands (ODiN).

In the remainder of this paper, we first provide an overview of the literature on post-pandemic effects of working from home and teleconferencing on travel behaviour in Section 2. Then, we provide a conceptualisation of the relationships between COVID-19, changes in working from home, teleconferencing and travel behaviour that we use as the framework of this paper in Section 3. Afterwards, we provide an overview of data and methods used for our analyses in Section 4. Section 5 then presents our results: first the developments in working from home and teleconferencing, followed by the expected effects on travel behaviour. Section 6 finally contains the discussion and conclusion.

2. Literature overview

This section will provide an overview of the existing literature on the structural effects of working from home on travel behaviour, after the COVID-19 pandemic will be over. To select papers for the overview, we queried the scholarly database Scopus on the 20th of November 2022 with the following query:

“TITLE-ABS-KEY((covid-19 OR coronavirus OR corona) AND ("Work from home" OR telecommut* OR teleconf*) AND (travel OR transport*) AND (effects OR results OR quantitativ*))”*

Of the 56 resulting documents, 15 papers were included. The main criterion used to include papers is that the papers should discuss the effects of working from home on travel behaviour after the pandemic. Most papers that were not selected either only discussed the effects of the pandemic on travel behaviour and/or working from home separately, or only discussed the relations or effects during the COVID-19 pandemic. The documents were then forward snowballed, meaning that we looked at the papers that cited a document in the original selection. As a result, 4 more papers were included. An overview table of all included papers is given in Appendix A.

Within a manuscript, up to three levels of headings may be used, not including the title of the manuscript. The first two levels are numbered, the third is not, but is typed in Italic. Figures, tables and mathematical expressions are numbered throughout the manuscript, not by section.

2.1 Working from home is here to stay after the pandemic will be over

The analysed papers overwhelmingly state that working from home is here to stay, as a substantial part of the people that increased the amount of time they worked from home during the pandemic state that they continue to work from home more after the pandemic than they did before it began. In the United States, roughly 40-50% of all workers expect to work from home at least a few times per month according to (Salon et al., 2022), which corresponds to a large majority of the adults that have the option to do so (Javadinasr et al., 2022). In a study in 20 European cities, roughly half of the respondents worked from home more often than they did before the pandemic (Christidis et al., 2022). In the Netherlands, roughly one-third of the working population expect to increase their working from home after the pandemic compared to before the pandemic (Olde Kalter et al., 2021).

Some papers raise the point that not everyone is able to work from home (Bohman et al., 2021). In studies in Europe and North-America, roughly half of the population was not able to work from home at all (Bohman et al., 2021; Javadinasr et al., 2022; Paul & Taylor, 2022; Salon et al., 2022). When designing policies that provide an advantage to people who work from home then, policy makers should be aware that these advantages will have distributional effects. Combined with the finding that the group that can work from home often consists of more highly educated and higher-income people (Bohman et al., 2021; Olde Kalter et al., 2021), such policies are likely to mainly benefit people who are already relatively well-off. This shows that policy makers should also focus on people who are not able to work from home and how they are affected by any policies related to this topic (Paul & Taylor, 2022).

2.2 Working from home will result in less commuting, but more leisure travel

In studies that analyse the structural effects of the COVID-19 pandemic as a whole on travel behaviour, working from home is often one of the primary drivers of structural differences in behaviour between the pre- and post-pandemic periods (Bohman et al., 2021; Christidis et al., 2021, 2022; Salon et al., 2022; Xu et al., 2022).

Studies show that working from home will have an expected negative effect on post-pandemic commute travel. Kogus et al. (2022) estimate a reduction of 6.5% and 8.7% commuting trips due to working from home in Israel and Czechia respectively. Javadinasr et al. (2022) expect that car commuting trips will go down by 9% and public transport commuting trips by 31% in the United States. An increase of 15% in working from home would result in a decrease of distance travelled by train of 8.3% in Switzerland (Manser et al., 2022). In Melbourne, decreases of commuting between 5% and 12.4% are expected, with larger decreases occurring in the inner region of the city (Currie et al., 2022).

Some studies also find expected increases in leisure travel. Christidis et al. (2021) assume based on an European survey that 50% of all avoided commute trips are replaced by retail or recreational trips instead. Campisi et al. (2022) find that people who spend more time working from home are more likely to travel for leisure purposes. They therefore emphasize that research should not only focus on the effects of working from home on commuting. Balbontin et al. (2022) find that people who work more from home make more shopping and recreational trips.

2.3 Strongest negative effect on public transport use

The effect of working from home varies over the various transport modes. All papers that have studied the effects of working from home on multiple travel modes seem to agree that public transport will be affected the most (Bohman et al., 2021; Currie et al., 2022; Downey et al., 2022; Javadinasr et al., 2022; Sweet & Scott, 2022). There are two principal reasons for this finding. First, people who can effectively work from home tend to use public transport to commute to their jobs more often. Second, commuting is a relatively large component of public transport use in many countries.

One often-reported finding is that people have shifted modes away from shared modes towards private ones (Bohman et al., 2021). This shift could exacerbate negative effects of working from home on the demand for shared transport modes such as public transport (Christidis et al., 2022; Paul & Taylor, 2022) and it could lead to increase use of less sustainable modes of transport such as the private car (Bohman et al., 2021; Christidis et al., 2021; Currie et al., 2022; Downey et al., 2022). This could lead to an increase in the use of the private car, despite potential negative effects of working from home on its use (Ceccato et al., 2022), although some studies find that the effect of working from home is large enough that a net-negative effect on car use can be expected (Olde Kalter et al., 2021).

Simultaneously a few studies report a shift towards the active modes of cycling and walking (Campisi et al., 2022; Currie et al., 2022; Downey et al., 2022), which could have benefits for the sustainability and accessibility of the transport system.

3. Conceptual Framework

In this section, we introduce and discuss the framework we used to guide the analyses in this paper. The framework consists of a set of relationships between working from home, teleconferencing and travel behaviour and is presented graphically in Figure 1. The framework is not meant as a complete conceptual model of working from home and its many antecedents and effects. Rather, it forms the basis of our analyses of the effects of working from home and teleconferencing on travel behaviour.

This study will primarily focus on the continuous arrows in the framework, whereas the dashed arrows are kept in mind when interpreting our results. We distinguish and analyse impacts of working from home and teleconferencing on trips and distances (3.1), mode use (3.2) and the spread of travel over the day and the week (3.3). On the longer term, we expect relationships between travel and working from home & teleconferencing to occur (3.4), which we discuss, but do not analyse in-depth, in this paper. Similarly, the shorter-term effects on travel behaviour might also result in reverse effects on working from home, which we also do not discuss in-depth in this paper. Finally, we aim to provide some first insights into the potential effects of the travel behaviour changes on policy goals of the government with respect to travel behaviour, focusing mainly on the implications for accessibility and sustainability (3.5).

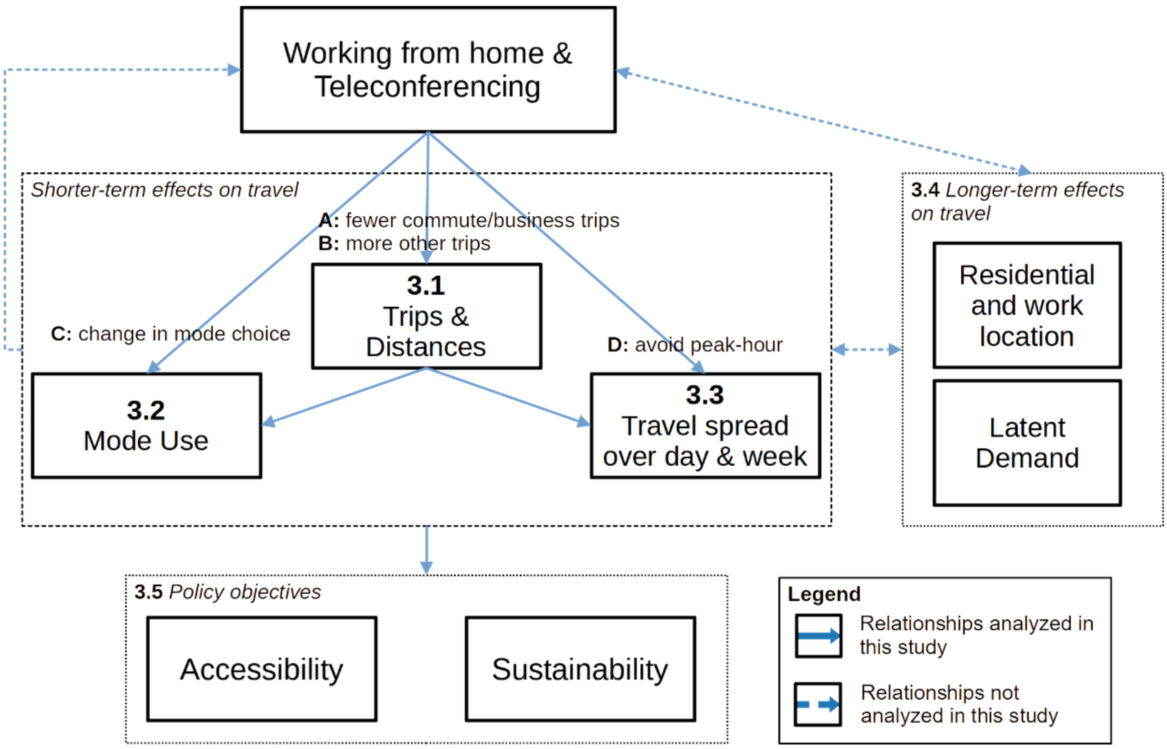

Figure 1. *Framework used to guide the analyses in this paper*

Below, we provide some explanations and references to literature that we used to conceptualize the framework.

3.1 Effects on trips and distances

We categorize the possible effects of working from home on the number of trips and travelled distance as follows (Andreev et al., 2010; Elldér, 2020; Salomon, 1986)

A. People travel less for commuting and business purposes, leading to reductions in trips and distances travelled. This is known as the substitution effect.
B. Because they save time, people travel more for other purposes. This results in an increase in trips and distances travelled. This is known as the complementary or complementation effect.

The net effect of working from home is the sum of the substitution effect and the complementary effect. As discussed earlier in Chapter 2 as well, recent research shows that the substitution effect is probably a little stronger, especially for people who work at home all day (Caldarola & Sorrell, 2022; Elldér, 2020). Nevertheless, the complementary effect should not be underestimated and could cause a smaller decrease in the number of trips than can be assumed based purely on the substitution effect (He & Hu, 2015; Kim, 2017). The existence of the complementary effect, especially in terms of travel time, could also be analysed in terms of a constant travel time budget (Ahmed & Stopher, 2014). Research into working from home and teleconferencing should be careful not to use a scope that is too narrow, by only focusing on the effects of working from home on commute and business travel.

3.2 Effects on mode use

Changes in working from home and teleconferencing could cause changes in mode use based on three separate effects:

A/B. People will travel less for commute and business trips, and they will likely travel more for other trips. Because travellers often use other means of transport for these purposes, the total use of the different transport modes will change as a result (Olde Kalter et al., 2021).
C. Although less likely, people could also use different modes for the trips they do make:
- For commuting and business trips, they might use the train more often because of the possibility to work remotely during the trip
- For leisure trips, they might walk more often than they did before COVID-19 as more trips are made in the vicinity of the residential location during the working day (Lachapelle et al., 2018).

We expect that the effects A and B, which are based on making fewer or more trips for specific purposes, are likely stronger than possible mode choice effects.

3.3 Effects on spread of travel

Changes in the spread of travel can occur because of:

A/B. Fewer utility trips and more leisure trips can lead to a different distribution of trips over the week. They can also cause traffic to shift during the day, from peak to off-peak hours (Stiles & Smart, 2021).
D. The digital possibilities to work from home or meet via teleconferencing might partly eliminate the need to travel during rush hours and enable travellers to delay the commute or business trip from peak to off-peak (Stiles & Smart, 2021; Su et al., 2021).

3.4 Longer-term changes in travel behaviour

In the longer term, we may observe additional effects. Working from home and teleconferencing can influence the work and residential location choices (Mokhtarian et al., 2004). For example, saving travel time is often a key factor behind the decision whether to start or continue working at home (Mokhtarian & Salomon, 1994); working from home thus makes it possible to live further away from the work location. Hensher et al. (2021) for example indicate that working from home may be a stimulus that increases suburbanization. Additionally, the changes in travel behaviour of the people who do work from home or teleconferencing may also induce changes in behaviour of other people. For example, if people who work from home will reduce their commute travel, that would reduce congestion. People who do not work from home will probably then be enticed by the faster average travel time on the road network to make more trips, make longer trips, or change their travel time to peak-hours. We refer to this potential phenomenon as latent demand in Figure 1.

3.5 Implications for policy objectives

Working from home can result in less commuting travel. This could potentially have a positive influence on the performance of the road network by reducing congestion. Furthermore, the increased uptake of working from home and teleconferencing might result in greater digital accessibility of these activities, as the digital alternatives become more accepted by employees and employers. However, the loss of public transport use might result in reduced transit service. This could be problematic for the accessibility of the transport system, in particular for people who are unable to work from home and depend on the public transport system to get them to and from critical activities such as work.

Regarding sustainability, working from home and teleconferencing can reduce the commuting trips by people who work from home. This could lead to reductions in total commute travel distance. However, people who work from home might also decide to accept longer commute distances per trip as total commute travel time throughout the week would then remain stable (Cerqueira et al., 2020), undoing some of the advantages. Furthermore, any sustainability benefits depend on the extent to which these trips might be compensated for by other, complementary travel and to the travel modes used for commuting. Nevertheless, literature seems to suggest that the net effect of working from home on sustainability is positive (see for instance Hamersma et al., 2021; Krasilnikova & Levin-Keitel, 2022; Moglia et al., 2021; van Lier et al., 2014).

4. Research Methods

In this section, we describe the research methods and data used to study the relationships described above. First, all data sources are described in section 4.1. Then the main steps of the analysis procedure are described in section 4.2. This is followed by an operationalisation of the main variables and a description of the final sample in section 4.3. Finally, the regression models are described in section 4.4.

4.1 Description of data sources

An important data source for our analyses is the Netherlands Mobility Panel (MPN; Hoogendoorn-Lanser et al., 2015). The MPN is a household panel that has been running since 2013 and consists of approximately 2000 complete households each year, corresponding to roughly 5000 respondents. Respondents are recruited from the Kantar NIPObase internet access panel in the Netherlands. This internet access panel recruits its respondents and does not allow for people to register themselves. New respondents for the MPN are recruited amongst the Kantar Access Panel yearly to account for panel dropout.

Every year in the fall, household members of at least 12 years old are asked to complete a three-day travel diary and fill in an extensive questionnaire that includes questions on topics such as work, outdoor activities and the use of different modes of transport. Furthermore, one person per household answers questions related to household characteristics, such as household composition and ownership of means of transport. In between the annual measurements, it is possible to use the panel for additional studies.

To study the impact of COVID-19 on activities and travel behaviour, we prompted a subsample of the panel to fill out a questionnaire and a three-day travel diary at six moments since the start of the COVID-19 pandemic. The subsample was drawn from the sample of MPN respondents who fully participated in the last two annual waves of the MPN at the time, which were the 2018 and 2019 waves.

This subsample consisted of 2750 respondents for the first COVID-measurement. The response rate of each measurement was roughly 90% for the questionnaire and between 80 and 85% for the travel diaries. These high response rates result from the fact that the subsample only uses respondents that already participated in earlier MPN waves. We invited people with a complete questionnaire for the following measurements. To increase the number of respondents and correct for skewed panel dropout, we invited 733 new respondents in the measurement of January 2021. These 733 respondents were also recruited from the group of MPN respondents that fully participated in the 2018 and 2019 annual waves. The net response rate for our last measurement of May 2022 was 1743 completed diaries and 1930 completed questionnaires.

We used weights to ensure the subsample would be broadly representative for the Netherlands, based on socio-demographic characteristics such as gender, age, educational and vocational background, location, and household composition.

Including the regular annual measurements in the fall of 2020 and 2021, we did 8 measurements among this selection of respondents so far during the COVID-19 pandemic in the Netherlands. The time of these measurements and the course of the pandemic in the Netherlands are given in Figure 2. The yearly waves are highlighted in green, the additional COVID-19 measurements are highlighted red. The blue line represents the 7-day rolling average of hospital admissions of COVID-19 patients.

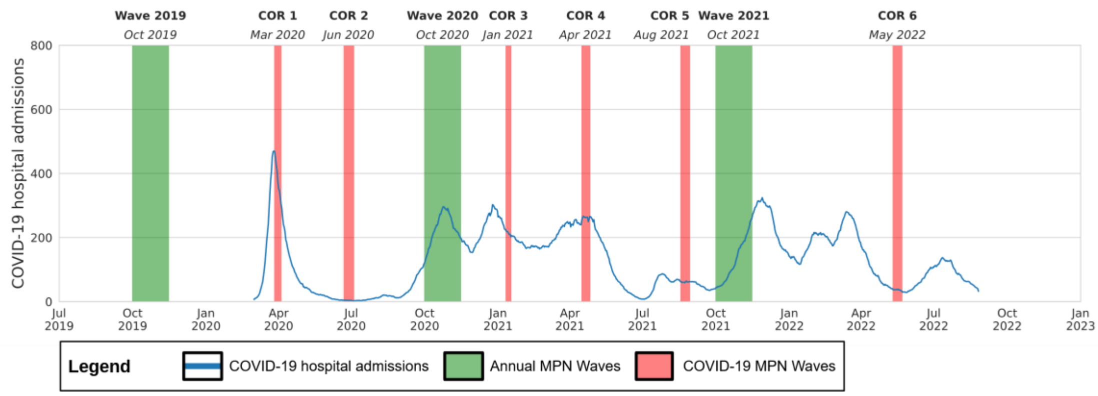

Figure 2. MPN measurements in relation to COVID-19 pandemic

The second dataset we use to estimate impacts on travel demand is the National Travel Survey of the Netherlands (called Onderweg in Nederland; ODiN). This cross-sectional individual survey is administered yearly by Statistics Netherlands, who use national registers to invite respondents. Respondents keep a 1-day travel diary and answer a shorter survey (compared to the MPN). In total, the ODiN contains 53 380 respondents, with a response rate of around 28% (CBS, 2022). As opposed to the MPN, the travel diaries are spread out throughout each calendar year, with respondents being assigned to a specific day of the year. Compared to the MPN, this dataset is much larger, but does not encompass information on working from home and lacks a longitudinal panel structure. In addition, there is no data available yet about 2022, when COVID-19 measures were lifted in the Netherlands. However, this dataset can be used to scale our findings up to the national level more accurately.

A comparison of the main differences between the three data sources is given in Table 1, as well as a very short summary of the main use in this paper.

Table 1. Comparison of the data sources used in this study

	MPN annual wave	**MPN COVID subsamples**	**ODiN**
Sampling unit	Household	Individual	Individual
Travel-diary	3 days. Collected annually around October	3 days. Collected at multiple phases of the pandemic in roughly 2-week waves	1 day. Collected year-round
Information on working from home	Both current and expectations	Both current and expectations	None
Longitudinal?	Yes	Yes	No
Nr. Of respondents	~2500 households; ~5000 individuals	Between 1750 and 2750 respondents	Roughly 50.000 respondents
Representative for the Dutch population	Broadly representative based on 8 socio-demographic indicators	Broadly representative based on 8 socio-demographic indicators	Representative and weighted to national level by Statistics Netherlands
Main purpose(s) in this paper	- Use pre-pandemic travel diaries to calculate effects of working from home on travel for specific mode and purpose combinations	- Describe developments in working from home during the COVID-19 pandemic - Use questionnaire to calculate effects of working from home and teleconferencing on travel per individual	- Scale up effects on travel behaviour within mode and purpose to effect on total travel demand - Calculate effects on travel distances and travel times

4.2 Analysis procedure

In this paper we give two separate types of quantitative results, corresponding to the sub-questions we identified in the introduction:

1. Descriptive statistics of developments in working from home, teleconferencing, and travel behaviour during the COVID-19 pandemic.
2. Calculations of expected effects of working from home and teleconferencing on travel behaviour after the pandemic.

This section will first present the different steps of the analysis procedure. The descriptive analysis is based fully on data from the MPN. We use the panel to describe developments in working from home and teleconferencing since the start of the COVID-19 pandemic until May 2022. These results are presented in section 5.1. Because of the panel design of the MPN, we can make comparisons using the same set of respondents across measurements both before and during the COVID-19 pandemic. We pay attention both to developments in actual behaviour and to the intended behaviour after the pandemic. We show some differences between subgroups of the sample. In addition, we use descriptive insights based on the MPN to complement our calculations in section 5.2.

The calculations of the effects of working from home and teleconferencing on travel behaviour are based on a combination of data from the MPN and ODiN. The idea is that we use the MPN to calculate mode- and purpose-specific effects of both working from home and teleconferencing. These calculations are based on people's intended working from home and mobility behaviours after the pandemic, as the last available measurement (May 2022) is very much within a transitionary phase right after the government scaled back most COVID-related measures. In this phase, behaviours have not yet stabilized into what might be called a post-pandemic 'new normal'. To map these mode- and purpose-specific effects to national travel behaviour, we then use the relative shares of such trips from the National Travel Survey ODiN. For example, if we find a reduction of 10% in commuting trips for the train using MPN-based modelling, we use the share of commuting trips for train travel in 2019 based on ODiN (~ 40%) to calculate an effect of roughly -4% (= 10% * -40%) on total train travel.

A graphical summary of this process is given in Figure 3 below.

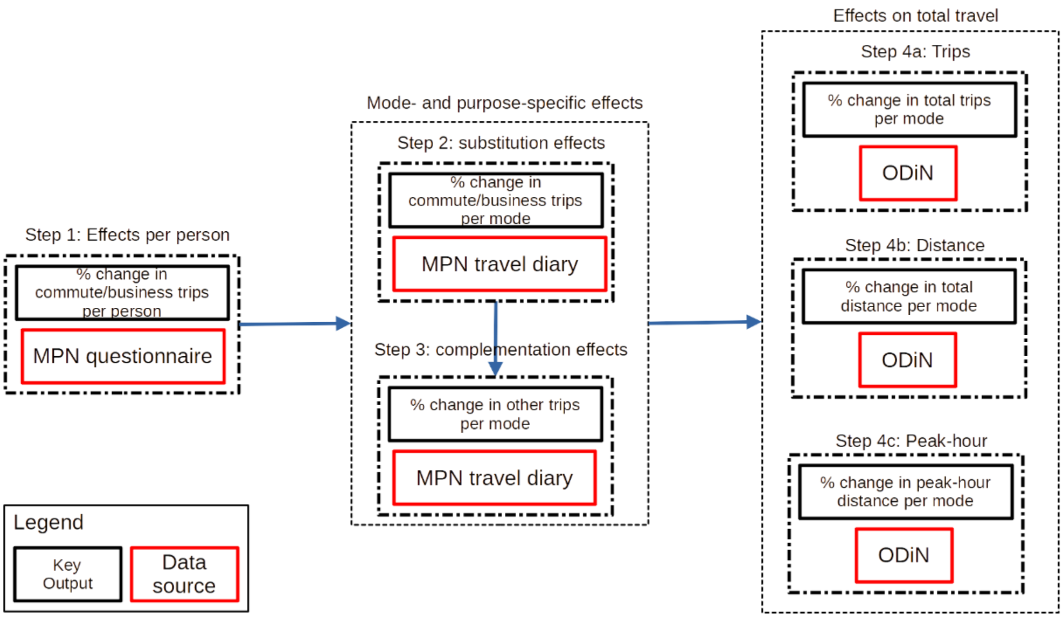

Figure 3. Structure of the analysis resulting in estimated effects on mobility

In the first step of the calculations, we try to determine the effects of working from home and teleconferencing on commute and business trips per person. To this end, we estimate two sets of regression models: one to estimate the effects on commute travel, and one to estimate the effects on business travel.

In the second step, we use the individual-level expected changes based on the regression models and combine them with travel diary information from before the pandemic to estimate the expected change in commute and business trips per mode. Effectively, we weigh the expected individual-level changes by the pre-pandemic travel behaviour of these individuals to calculate trip-level changes. For example, if people with a higher expected change in working from home travelled more by public transport for commuting before the pandemic, then public transport will be affected by working from home to a greater extent.

As discussed in section 3.1, we then need to take the complementation effect into account (step 3). This complementation effect compensates, at least to some extent, for the substitution effect. If we do not account for this effect at all, then we will overestimate the effect of working from home on travel behaviour. However, we do not think we can adequately assess the strength of the complementation effect using a questionnaire. Nor can we use data gathered during a pandemic to estimate its effects and extrapolate that to a world after the pandemic. Therefore, we must for now use assumptions instead. We assume that a reduction in commute trips because of working from home will be compensated by an increase in leisure trips of between 0 and 75% of the reduction in commute trips.

This numerical assumption is based on three pieces of evidence. First, a comparison of travel patterns of people who work from home and people who work on location based on pre-COVID data, which indicates that people who intensively work from home travel a bit less than people not working from home (Hamersma et al., 2021). Second, a longitudinal panel study that studies the effects of working from home on commute travel time and leisure travel time, which shows that the latter effect indeed exists and is positive but is less strong than the negative effect on commute travel time (Faber et al., 2023). Third, our latest MPN-measurement also shows that a significant part of respondents indicate that they travel less on a day where they work fully from home, compared to a day where they make a trip to the work location (Figure 4). However, a substantial amount also indicates that they travel the same amount or not much less.

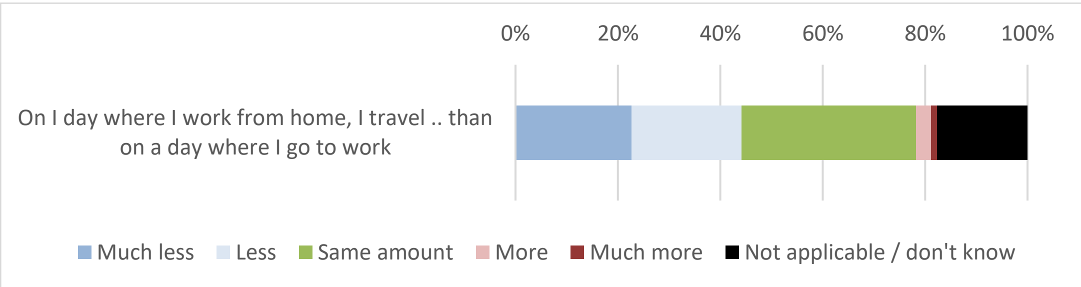

Figure 4. ***Amount of travel on a day working from home, compared to a commuting day (Data: MPN, COVID-Measurement of May 2022, N = 955)***

In summary, there is quite a bit of uncertainty about the size of the complementation effect. That uncertainty is reflected in the calculations by the relatively wide range of the size of the possible complementation effect, which compensates between 0 and 75% of the reduction in commute trips with an increase in trips made for other purposes. We do not foresee any such compensatory trips because of the reduction in business trips, because business trips normally take place during working hours and are not likely to be compensated outside working hours in the form of leisure travel.

Steps 2 and 3 result in mode-specific changes to commuting, business, and leisure trips. Using data from ODiN 2019, we calculate the net effect on mode use (step 4). Effectively, we use the share of purpose-specific trips, distances, and distances during peak-hours. We make these calculations for the number of trips (step 4a), the travelled distance (step 4b), and the distance travelled during peak-hours (step 4c).

4.3 Operationalisation and Sampling

The main concepts used in the analyses steps of this paper relate to travel behaviour, working from home, and teleconferencing. This section will explain the operationalisation of these concepts into variables. We will also describe the sampling procedure for each of the analysis steps described in the section above.

Working from home and teleconferencing
Working from home is measured in both the annual waves and the COVID-waves, by asking the average number of hours people spent working from home in the last few weeks. Similarly, people were also asked to answer how many hours they expect to work from home in the future after the COVID-19 pandemic would be fully over and all restrictions would be lifted. The difference between the number of hours people worked from home in the last annual wave before the pandemic and the intended number of hours they would work from home after the pandemic is then used as an independent variable in the analysis. Effectively this variable captures the effect of a change in working from home during the pandemic on travel behaviour.

For teleconferencing, we do not have such a baseline of behaviour before the pandemic, as no questions relating to teleconferencing were included in the last annual pre-pandemic wave. Instead, respondents are asked whether they think they will hold more online meetings in the future after the pandemic is over than they did before the pandemic began:

"Do you expect to hold digital meetings more or less often in the future on the longer-term, given that there are no COVID-related restrictions?'"

Respondents could answer using seven answer categories, ranging from 'Much less often' to 'Much more often'. Given that almost no respondents indicated that they would do so much less often or less often, we combined these categories with the category that indicated no change in our analysis.

Travel Behaviour
Travel behaviour is measured both using the questionnaire and the travel diary of the MPN, as well as the ODiN travel diary. The regression models estimate the individual-level effect of working from home and teleconferencing on the number of days that people expect to travel for a specific purpose in the future.

For commuting trips, this is the number of days per week, with possible answers ranging from zero to seven days per week. We asked respondents to indicate whether they would travel on a certain day of the week for commuting purposes: *"Can you indicate on which days of the week you intend to commute in the future on the longer term, when all covid-related restrictions have been lifted?"*. We then summed up the number of days they indicated to get the number of days with commuting trips per week. Respondents were also asked to retrospectively indicate on which days they commuted before the COVID-19 pandemic.

For business trips, which are typically undertaken much less frequently than commuting trips, we asked for the intended number of days per year with the following prompt: *"How often will you travel for business-related purposes on the longer-term, when all covid-related restrictions are gone?"* Respondents could answer in six categories, ranging from '(almost) never' to '4 or more days per week'. Respondents were also asked to retrospectively answer the same question for the time before the COVID-19 pandemic, which we used as an independent variable.

We also record travel behaviour using trip diaries, which are used in steps 2, 3, and 4 of the analysis as visualized in Figure 3. For the MPN, the trip-diaries are used to weight the individual-level effects to mode- and purpose-specific effects. The ODiN travel diaries are used to calculate nationally representative shares of each purpose within each mode, which allows us to calculate the effects on total travel demand.

4.4 Description of final sample
The expected effects of working from home and teleconferencing on the behaviour of an individual is only calculated for people with gainful employment, as other groups of the population are not affected by working from home at all (and they also make no commuting / business trips). However, the effects we are interested in are the effects on total travel, of all people.

The MPN sample that is used to describe the developments in working from home and teleconferencing then consists only of individuals with gainful employment. A total of 955 complete respondents are used. The ODiN sample used to scale these findings to the national travel demand consists of all people within ODiN 2019, which were 53 380 respondents. The distribution of some socio-demographic variables within the two samples is given in 0.

Regression model specification and estimation
As explained in section 4.2, we estimate two regression models to estimate the post-pandemic effects of working from home and teleconferencing on commute and business travel. The main idea behind the regression analyses is that we regress the future intended number of days with commute/business trips post-pandemic on five distinct categories of variables:

1. The number of days with commute/business trips before the pandemic
2. A set of socio-demographic variables pertaining to the individual
3. A set of regional characteristics of the region where the respondent lives
4. The intended change in working from home
5. The intended change in teleconferencing

This approach is similar to the approaches of Melo & de Abreu e Silva (2017) and Caldarola & Sorrell (2022), with the exception that we have access to panel data. Our main interest is in the effects of variables 4 and 5 since these variables capture the effects of working from home and teleconferencing on travel behaviour change. We control this effect for socio-demographic (2) variables, including life-events, and regional (3) variables. Due to the availability of panel data, we can also control for the number of days with commuting or business trips before the pandemic (1). If people intend to have the same number of days with commuting or business trips after the pandemic as they did before the pandemic, then all variance of the dependent variable would be explained by these number of days of commuting or business trips before the pandemic. As a result, the other variables' estimates effectively pertain to the change in working from home and teleconferencing, respectively. We are also able to control for the effects of life-events, which are part of the socio-demographic variables (2).

The dependent variable in both analyses is the intended number of days with either commute or business travel, as introduced in Section 4.3.1. The commute-specific dependent variable is a count variable, with a maximum of seven (days per week). For this reason, we estimate a Poisson-regression model, as a regression model that uses OLS estimation will provide inefficient and biased estimates (Long & Freese, 2006). Strictly speaking, the business dependent variable is an ordinal variable. However, we treat it as a continuous variable by using numerical values corresponding to the middle of each category and do estimate a linear regression model using OLS. Furthermore, we assume in the interpretation of our results that these variables, which are measured in days, can be translated directly into changes in trips. Effectively, we assume that the reductions in terms of number of days with business or commute travel are directly proportional to the reductions in business or commute trips, respectively.

5. Results

This section contains the results from our analyses. The section is split into two parts. In the first, we use descriptive analyses to describe the developments in working from home and teleconferencing. In the second part, we describe the results from our calculations into the effects of working from home and teleconferencing on travel behaviour. More descriptive analyses using the same data can be found in de Haas et al. (2022).

5.1 Descriptive analyses

This section contains the descriptive analyses of the developments in working from home and teleconferencing during and after the COVID-19 pandemic.

Since the start of the COVID-19 pandemic, our respondents have drastically increased the numbers of hours they work from home per week. Before the start of the pandemic (October 2019) about 30% of our working respondents worked at home at least an hour per week. This increases to about 50% during the pandemic.

Figure 5 shows the average number of hours people spent working from home per week in May 2022. Aside from the total average, the number of hours is also given grouped by the main mode that people used to commute to work right before the COVID-19 pandemic started, which we determined using the questionnaire of the 2019 MPN wave. We observe that the average number of hours working from home per worker per week in May 2022 is more than two times higher than before the start of the COVID pandemic (before 3h per week; now 6.5h per week). People expect that this will decrease slightly in the next few months as we further transition to a new situation, to an average of 6h per week.

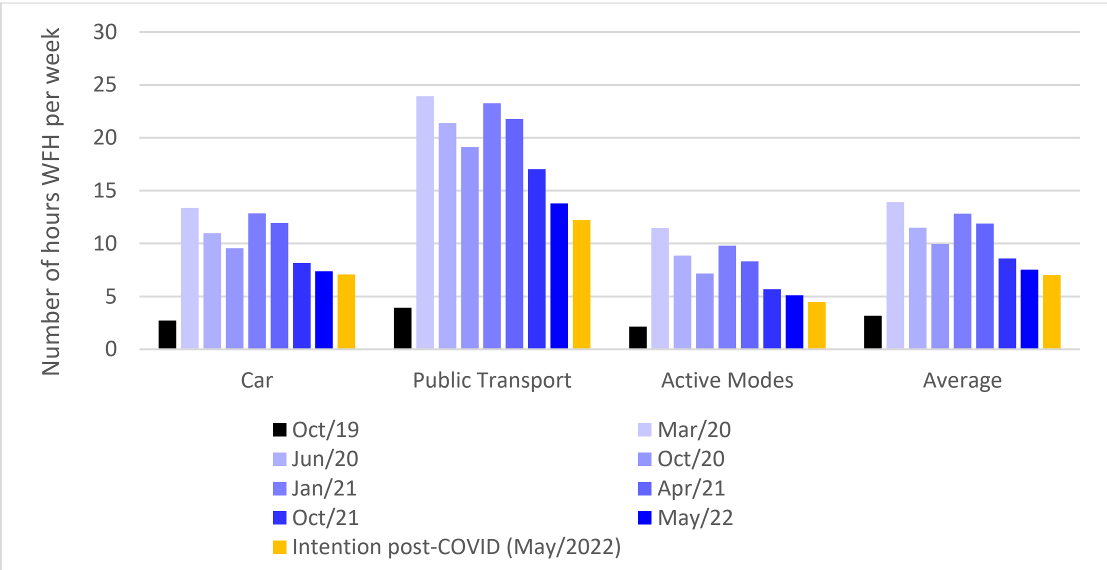

Figure 5. Average number of hours worked from home per week, grouped by the main commute mode used before the pandemic (Data: MPN questionnaire, all measurements since October 2019, N = 955)

The intended increase in working from home compared to before COVID is much larger among those who travel to work by public transport (from approximately 3.5h to 14.5h), compared to people who commute by car or cycling/walking (Figure 5). In addition, the intended increase is higher for people who attained (applied) university education (from approximately 5h to 11), for the people living in urban areas (from approximately 3h to 6.5h) and among those with an office job (from approximately 4h to 12h) or a management function (from 4h to 9h). We also observe stronger intended increases for people who work in larger organisations and for those with longer commuting times (for the latter, see also Hamersma et al. [2021]).

The use of digital technologies to meet with people for work purposes, which we refer to as teleconferencing, has increased since the beginning of the pandemic as well, as evidenced by Figure 6.

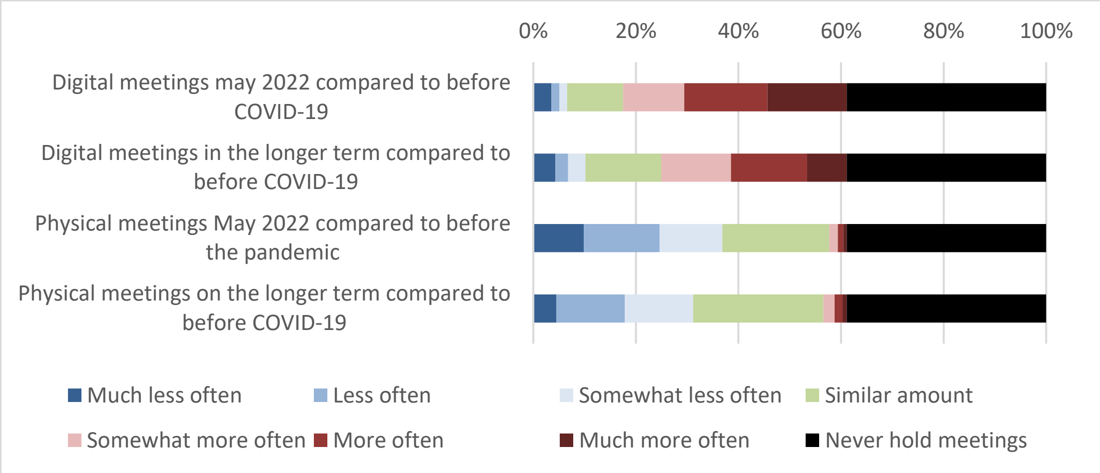

Figure 6. Current and intended amount of physical and digital meetings compared to pre-COVID (Data: MPN COVID-measurement of May 2022, N = 955)

Most of our respondents indicate that even in May 2022, they are still using teleconferencing much more often compared to before the pandemic. Furthermore, their intention is to continue doing so after the pandemic, although not quite as often as now. Physical meetings then seem to become less common, although a substantial number of our respondents indicate no change. Still, this is an indication that digital meetings are substituting physical meetings to some extent. Employees in care jobs and jobs in field service are less likely to reduce the number of physical meetings than the other distinguished job types. In larger companies, the share of employees who have reduced the number of physical meetings is larger than in smaller companies.

5.2 The effects on travel behaviour

This section contains the estimated effects of working from home and teleconferencing on travel behaviour. Following the steps identified in section 4.2, we first report the regression model estimates. This is followed by a range of expected mode- and purpose- specific effects, as calculated using the regression coefficients and travel diary data from the MPN. Then, these effects are used to calculate the effects on total travel demand, both in terms of trips, distances, and peak-hour distances using weights provided by ODiN. Finally, we discuss the possible effects of shifts in mode choice and spreading of travel per trip purpose.

Regression model estimates

The model estimates for the effects of changes in working from home and teleconferencing on the expected changes in commute and business travel are provided in Table 2. The full model estimates, including coefficients relating to the other exogenous variables, are given in Appendix A.

Table 2. Parameter estimates of working from home and teleconferencing on intended travel behaviour (Model based on data from MPN questionnaires)

		Dependent variables	
Variable	**Levels**	**Intended number of weekly days with a commuting trip[1]**	**Intended number of yearly days with a business trip[2]**
Intended increase in working from home (Hours per week)	Does not work from home	Ref.	Ref.
	Works less than 8h per week	-0.528***	-0.818
	Less than 6h	-0.004	3.77
	6 – 13	-0.230***	-4.65*
	14 – 20	-0.438***	-5.92***
	21 – 28	-0.757***	-7.355*
	More than 28	-0.949***	-18.779***
Change in teleconferencing	No teleconferencing	Ref.	Ref.
	Less often or equal	0.036	-2.316
	A bit more often	0.056	-3.204
	Much more often	-0.071	-12.1***
Model statistics	N	955	
	Log-Likelihood	-1797.2	-4366.3
	Pseudo-R^2	0.312	
	Adjusted R^2		**0.**799
1: estimates from a Poisson regression model; 2: estimates from an OLS regression model			
*p<0.1; **p<0.05; ***p<0.01			

The estimated parameters for the intended increase of working from home have a strong effect on both the intended commute and intended business travel. Very few other parameters (see 0) are statistically significant, indicating that it is indeed the change in working from home that is the main driver behind the change in commute and business travel. Only people who have the intention to teleconference much more often also intend to travel less often for business purposes. Using these estimates, we can calculate the expected effects of increases in working from home and teleconferencing on commute and business travel after the pandemic.

For commute travel, we use the rate ratio (the exponent of the coefficient), which gives us the percentage change in the dependent variable, the intended number of days in a week where people will commute, that is associated with an increase in working from home for every individual. For example, this ratio for someone who expects to increase working from home by between 6 and 13 hours is equal to 0.795 (exponent of -0.230), which means that the intended percentage change in commute trips post-pandemic compared to pre-pandemic due to working from home for this individual is -20.5% (= (0.795 – 1) * 100). For business travel, we use the OLS-parameter coefficients directly to estimate the change in the number of business trips of working from home and teleconferencing for every individual. For example, someone who has the intention to increase their working from home by between 6 and 13 hours is expected to decrease their business trips as a result of the pandemic by 4.65 more trips than people who do not work from home. For both business travel and commute travel we calculate a lower- and upper bound for the effect by using the values of the parameters of a 95% confidence interval.

Purpose specific effects

The estimates from the regressions thus provide us with expected changes because of working from home and teleconferencing for commuting and business travel for every individual. Now, it is important to realize that the total expected change in travel is not the mean change per individual. First, we need to weight by the frequency of travel with each travel mode for every individual. For example, if people who started to work from home more than 28 hours during the pandemic only travelled by train, then only the use of this mode is affected by the change in commuting due to this change in working from home.

To provide mode-specific estimates then, we use the travel diaries of the MPN. More specifically, we use the travel diaries from 2018 and 2019, the last two measurements before COVID. All respondents of the additional COVID-measurements partook in these yearly waves as well. We then calculate the mode-specific average of the effects across the relevant trips in these diaries, using the individual-level values calculated using the regression coefficients.

The resulting estimates for the effects of working from home and teleconferencing on the number of mode- and trip-specific trips for commuting and business purposes is given in Table 3. This table contains a 95% confidence interval of the expected effect within each mode- and purpose. Since business trips were very rarely made either using bus, tram, metro (btm) or on foot, it is impossible to calculate reliable estimates for the effect on business travel for these modes.

Table 3. Expected range of changes1 in commuting and business trips due to working from home and teleconferencing per mode (Results based on MPN questionnaire and travel diary)

	Car	Train	Bus, Tram, and Metro	Cycling	Walking
Trips (change in mode- and purpose-specific trips)					
Commute	(-7%, -15%)	(-14, -26%)	(-10, -19%)	(-4%, -9%)	(-9%, -17%)
Business	(-2%, -12%)	(-4%, -22%)	-[2]	(-2%, -22%)	-[2]
1: based on a 95% confidence interval of the regression-model parameters					
2: too few pre-pandemic btm and walking business trips to provide a reliable estimate					

To estimate a mode-specific complementation-effect, we then need to calculate the reductions in commute travel per individual and estimate corresponding increases in travel for other purposes. We therefore use the assumption that between 0 and 75% of the commuting trips are compensated by trips for other purposes (see also section 3.1). We need to take two things into account:

1) Only individuals who decrease their commute travel will increase their travel for other purposes.
2) People who decrease their commute travel more strongly will increase their travel for other purposes more strongly as well

We take this into account by estimating the upper-bound of the reductions in commute trips for each level of working from home used in the regression analysis. For example, for the people who intend to increase the number of hours worked from home between 6 and 13 hours this upper bound is 31%. We then use the mode share for other purposes of each of these groups to translate these reductions in commute trips to increases in other travel per mode. These people make almost 3x as many other trips as commute trips, so this would correspond to an increase in other trips of roughly 10% within this group. We assume that up to 75% of the non-made commute trips are compensated by other trips, resulting in an increase of other trips for this specific group of 7.5%. The expected increase for groups who do not intend to increase their working from home of course are 0%, whereas the expected increases for groups who intend to work more hours is larger. We use a weighted mean of these expected increases within each group for each mode to calculate the expected mode-specific effect size. The resulting increases in trips for other purposes are given in Table 4.

Table 4. Expected range of changes1 in other trips due to working from home per mode (Results based on MPN questionnaire and travel diary)

	Car	Train	Bus, Tram, and Metro	Cycling	Walking
Trips (change in mode- and purpose-specific trips)					
Other	Up to 4%	Up to 7%	Up to 7%	Up to 3%	Up to 3%
1: Minimum effect is 0%. Maximum effect is based on 75% of maximum decrease in commuting trips.					

Effects on total travel demand

Now that we have the three components of travel change due to working from home and teleconferencing, we can work out the estimated combined effect on total travel demand. We calculate the effects on three indicators: the number of trips made, the travel distance, and the travel distance during peak-hours (Figure 3). To do so, we use data from OdiN 2019. Effectively, we are using the national travel survey to weight the within-purpose change to the total change for each purpose. For example, since business travel is relatively less frequent, the within-business effects only result in relatively minor changes in total travel. To calculate the effects on distance travelled, we assume a directly proportional relationship between the effects on trips and the effects on distance. In other words, we assume that people who have the intention to reduce commute trips due to increases in working from home travel for the same distance as people who do not do so, *conditional* on the mode they travel with (since we use mode-specific effects). The effect on travel spread is then calculated using the shares of commuting and business travel in total travel in the morning and evening peak. We thus calculate only the effects of reductions in commute and business trips and increases in other trips. We do not yet take potential additional shifts away from peak-hours into account.

Table 5 presents the results of the impact of changes in commuting, business trips and trips for other purposes because of working from home and teleconferencing (A and B in Figure 1). These results again show an upper- and lower bound of the expected effect.

Table 5. Expected range of changes in total travel due to working from home and teleconferencing per mode (Results based on MPN estimates, projected using ODiN data to get national-level statistics for total travel distance)

	Car	Train	Bus, Tram, and Metro	Cycling	Walking
Total trips					
Commute[1]	(-3%, -1%)	(-10%, -6%)	(-5%, -3%)	(-2%, -1%)	(-1%, 0%)
Business[1]	(-0.3%, -0.1%)	(-0.7%, -0.1%)	N/A	(-0.1%, 0%)	N/A
Other purposes[2]	Up to 1%	Up to 1%	Up to 2%	Up to 1%	Up to 1%
Net effect[3]	(-3%, 0%)	(-11%, -4%)	(-5%, -1%)	(-2%, 0%)	(-1%, 1%)
Total travel distance					
Commute[1]	(-4%, -2%)	(-8%, -5%)	(-5%, -3%)	(-2%, -1%)	(0%, 0%)
Business[1]	(-0.8%, -0.1%)	(-0.9%, -0.2%)	N/A	(-0.1%, 0%)	N/A
Other purposes[2]	Up to 1%	Up to 2%	Up to 1%	Up to 1%	Up to 2%
Net effect[3]	(-5%, -1%)	(-9%, -3%)	(-5%, -1%)	(-2%, 0%)	(0%, 1%)
Travel distance during morning peak-hours					
Commute[1]	(-10%, -5%)	(-16%, -9%)	(-10%, -5%)	(-4%, 0%)	(-1%, -1%)
Business[1]	(-1.2%, -0.2%)	(-0.9%, -0.2%)	N/A	0%	N/A
Other purposes[2]	Up to 1%	Up to 1%	Up to 1%	Up to 1%	Up to 5%
Net effect[3]	(-12%, -5%)	(-17%, -8%)	(-10%, -5%)	(-4%, 1%)	(-1%, 1%)
Travel distance during evening peak-hours					
Commute[1]	(-6%, -3%)	(-12%, -7%)	(-8%, -4%)	(-3%, -1%)	(-1%, 0%)
Business[1]	(-0.9%, -0.2%)	(-0.2%, -1.1%)	(0%, 0%)	(0%, -0.2%)	(0%, 0%)
Other purposes[2]	Up to 1%	Up to 2%	Up to 2%	Up to 1%	Up to 2%
Net effect[3]	(-7%, -2%)	(-13%, -5%)	(-8%, -3%)	(-4%, 1%)	(-1%, 1%)
1: Range is based on 95% confidence interval of regression model					
2: Lower limit is 0%. Upper limit is 75% of the maximum effect on commuting.					
3: Range is based on combination of 95% confidence interval of regression model and uncertainty range of complementation effect					

The calculations show clearly that train and btm-trips are more strongly affected when compared to the other travel modes. We saw before (Figure 6) that public transport travellers have increased their amount of working from home more than other travellers.

Whereas a net negative effect is expected for train, BTM, and to a lesser extent car and cycling, a positive effect is expected for walking. This is because the expected complementation effect seems to outperform the substitution effect (of lesser commuting and business trips) for walking. The main underlying reason is that few people walk for commuting or business travel, whereas many do so for other purposes.

We find that the effects on commuting are the main driver behind potential changes due to working from home and teleconferencing. This is because commuting is a much more frequent purpose when compared to business travel, which is relatively rare. As a result, even relatively substantial changes in business travel only have comparatively small effects on total travel.

The impacts on trips are comparable to the impacts on distances. Of course, this is a result of our assumption that the relative effect on distances is directly proportional to the effect on trips, conditional on the travel mode that is used. Effectively, the remaining differences then reflect the fact that the average distance travelled differs across the commuting, business, and other purposes. For the car, the effect for the commuting purpose in terms of distances is slightly larger than the effect in terms of trips. This reflects that for the car, the average distance travelled for commuting is larger than the average distance travelled for other purposes. The opposite is true for the train, resulting in comparatively smaller effects in terms of distances than in terms of trips.

The negative effects on travel behaviour are likely to be stronger in the morning peak (for example, for the car it is estimated to be -5 to -12%, compared to -1 to -5% on overall travel). This is because a relatively large share of travel in the morning peak consists of commuting travel. The effect in the evening peak is less strong than the effect in the morning peak because the evening peak consists of much more trips made for other purposes comparatively.

Changes in mode choice and purpose-specific spread of travel

As mentioned, in the above analyses we did not (yet) account for changes in mode choice for commuting-, business- or other trips (C, Figure 1), and potential shifts from on-peak to off-peak travel due to more working from home or teleconferencing (D, Figure 1). We analyse these possible effects using data from the special COVID-questionnaires of the MPN.

Regarding commute mode choice, we asked our respondents with which travel mode they would predominantly commute in the future after the COVID-19 pandemic would be fully over. We also asked them which was their main commute mode before the COVID-19 pandemic started. We do see some shifts here, mainly away from public transport towards the car and the active modes. However, the frequency of these mode shifts is not correlated with the intention to work more from home after the pandemic is over, as is shown in Table 6.

Table 6. Crosstabulation of intention to work from home and intention to change the main commute mode (Data: MPN questionnaire, measurement of May 2022. N = 955)

	No mode shift	Mode shift
Not working from home	388 (80%)	98 (20%)
No increase	82 (81%)	19 (19%)
Increase	220 (79%)	59 (21%)

A Chi-square test (1.75, df = 3, p = 0.63) shows that there are no statistically significant differences between people who do not work from home, people who do not intent to increase the number of hours they work from home as a result of the pandemic, and people who do intent to do so when it comes to an expected mode shift for commuting. As a result, we do not expect that working from home will have an effect on commute mode choice. We have no very clear indication for the future intentions regarding mode choice of other travel. However, we did see large increases in the mode share of cycling and walking during the pandemic. For this reason, we expect a small mode shift towards the active modes for other travel.

Regarding peak-hour avoidance (D), we asked respondents whether they think they would travel less during peak-times when commuting after the pandemic than they did before the pandemic in our COVID-measurement of April 2021. (Figure 7).

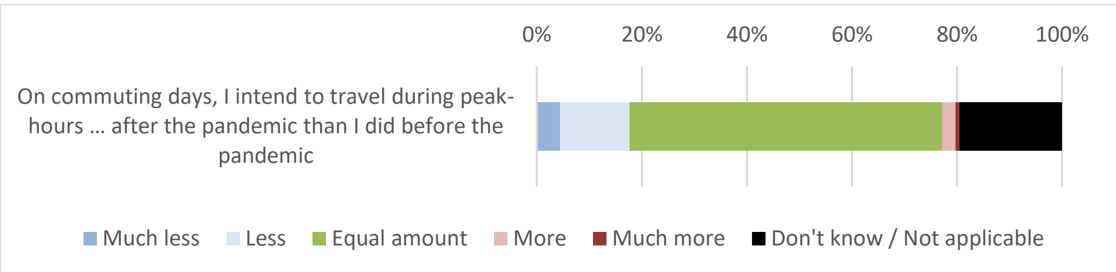

*Figure 7. **Respondents’ intended change in peak travel on days they need to go to work, compared to pre-COVID (Data: MPN COVID-Measurement April 2021, N = 955)***

Only a relatively small percentage of respondents (< 20%) intended to travel less during the peak after the pandemic, with most respondents indicating that they either intended no change or couldn't answer the question. Respondents thus seem to indicate that they do not think that working from home or teleconferencing will lead to a noticeable shift towards off-peak travel, at least if no further measures are taken by either the government or employers.
We do expect small structural changes in the spread of commuting travel over the week. Although people on average intend to travel less for work on all days of the week due to more working from home and teleconferencing, Tuesdays and Thursdays are still the days with the most commutes. Wednesdays and Fridays are likely to become even less popular days to go to the office than they already were.

Table 7 summarizes the findings regarding the effects on trips (A+B), and the effects of mode choice (C) and spread of travel (D) for each main travel mode.

Table 7. Table 1: Summary of all expected travel effects due to more working from home and teleconferencing

	Car	Train	Bus, Tram, and Metro	Cycling	Walking
A+B Distance travelled					
Total	(-5%, -1%)	(-9%, -3%)	(-5%, -1%)	(-2%, 0%)	(0%, 1%)
Morning peak	(-12%, -5%)	(-17%, -8%)	(-10%, -5%)	(-4%, 1%)	(-1%, 1%)
Off peak	(-3%, 1%)	(-5%, 0%)	(-3%, 0%)	(-1%, 1%)	(0%, 1%)
Evening peak	(-7%, -2%)	(-13%, -5%)	(-8%, -3%)	(-4%, 1%)	(-1%, 1%)
C Mode choice					
Commute and business	No substantial effect expected				
Other travel	Negative	Negative	Negative	Positive	Positive
D Peak avoidance					
Day	No substantial effect expected				
Week	Less commute travel on Wednesday and Friday				

6. Conclusion and discussion

COVID-19 has accelerated the trend of an increase in working from home and teleconferencing in the Netherlands, as well as in many other countries. This study aimed to answer two questions. First, what are the expected structural, post-pandemic changes in working from home and teleconferencing and second, what effects will these changes have on travel behaviour. To do so, we used both panel data and a national-level cross-sectional travel survey.

Our findings show that there will be structural increases in working from home and teleconferencing due to the pandemic. We base this conclusion both on the drastic increase of working from home and teleconferencing during the pandemic, as well as on people's intentions for the post-pandemic future. Findings show that the levels of working from home and teleconferencing as of May 2022 were still a bit higher than people's post-pandemic intentions. This means that as of May 2022, we were still in a transitionary phase after the Dutch government relaxed most of the COVID-related measures since March 2022. In addition, it is important to stress that working from home is impossible for roughly half of the workforce in the Netherlands. The half that can work from home more often consists of office- and managerial workers with a relatively high level of education.

Regarding the effects on travel behaviour, our findings suggest that the structural impacts on public transport and on morning peak travel are the strongest. This is because people commuting by public transport are more likely to work from home and that commutes are a relatively large part of (especially) morning peak travel, respectively. We estimate that structural, post-pandemic increases in working from home and teleconferencing will result in a negative effect on distances travelled by train (-3% to -9%) and by bus, tram, and metro (-1% to -5%). The estimated effect on the distance travelled by car (-1% to -5%), bicycle (-2% to 0%), and walking (0% to +1%) is smaller.

Discussion

These findings indicate that structural changes in working from home and teleconferencing due to COVID-19 have important implications for the accessibility and sustainability of the transport system. The sizeable reductions in commute travel are likely to lead to a more spread-out travel demand, which could relieve congestion on roads and crowding in public transport. This finding is generally congruent with expectations and other results in the literature (Campisi et al., 2022; de Vos, 2020; van Wee & Witlox, 2021). However, there are some potential drawbacks to discuss. First, the size of the structural impacts on car travel seems to be limited and thus should not be overemphasized, especially against the backdrop of expected population growth and welfare increases. Second, the effects on public transport are stronger, which is a point of concern, at least on the shorter term (Tirachini & Cats, 2020). This result echoes general results and expectations in the literature, as found in Chapter 2. The lower number of passengers could result in less financial capacity to assure the quality of public transport. Lower-quality public transport would then drive people into other modes of transport, potentially creating a damaging spiral. When looking slightly further ahead, up to 2027, it is however important not to overestimate the total effect of working from home on public transport travel. Population growth and expected economic developments mean that demand (also for public transport) is still likely to exceed pre-pandemic public transport levels within these next five years, at least if service levels will not continue to be affected by lack of personnel (Kennisinstituut voor Mobiliteitsbeleid, 2022). The increase in working from home and teleconferencing thus mainly has a dampening effect on traffic growth. When considering the usefulness and necessity of infrastructure investments, it is important to be aware of this broader perspective.

Policy Recommendations

Based on our findings, working from home and teleconferencing have some desirable effects on the transportation system. The digital means of accessing the workplace allow a substantial share of people to forgo their physical commute. This reduction in commuting trips will likely lead to a travel pattern that is more spread out across the day, further reducing congestion even at similar total demand levels. There are however also some undesirable effects, especially regarding the public transportation system which sees a substantial drop in its use. This might also have repercussions for people who are not able to work from home, especially when the service levels of public transport would be adjusted to the lower demand. Such adjustments could result in more car dependency, which should be avoided as it would have negative effects on both the accessibility and the sustainability of the transport system.

From a transportation perspective, employers and governments should then probably try to strike a balance where some amount of working from home is facilitated, perhaps encouraged, but not enforced. To do so, employers could formalize the right to work from home in employment contract, provide facilities for hybrid meetings and pay for home office setups of employees. From a transportation perspective, they should also pay particular attention to spread travel and work location visits over the days of the week. Governments can introduce legal frameworks for flexible working, including working from home. They can simplify or expand fiscally attractive options for employers to pay for employees’ home office setups and simplify hybrid work regulations. They too should try to encourage people to spread their office visits throughout the week and the working day. They could also look outside of the employment sphere, for example by introducing pricing schemes to discourage peak-hour travel on certain days or look at the educational system to facilitate working parents.

Limitations

There are some limitations of this paper that need to be discussed. First, it is important to mention that although we used data collected at a time when nearly all COVID-measures were lifted, the actual effects on travel still contain some uncertainty that is not already reflected in the results. For example, we observe that the level of working from home and teleconferencing in May 2022 was still above the intended levels for the longer term (so long as measures are lifted). Regarding these intentions, it still needs to be seen whether they will be fully reflected in future behaviour. However, the intentions of respondents turn out to be rather stable over time and match recorded behaviour well. Second and related to the first point, we use stated intentions to estimate the structural effects. It would be interesting to use actual behaviour as the dependent variable in the future, when we have fully transitioned out of the pandemic. We could then also empirically test the critical assumption underlying our calculations regarding the complementary effect. Research into the relative strength of this effect, and more broadly into the validity of the constant travel time budget (Ahmed & Stopher, 2014) is necessary after the pandemic will be behind us. Third, we explicitly did not yet account for potential longer-term effects on people's residential and work location choices. It could be that people at least partly account for this in their intentions regarding working from home and commuting trips. We did ask people if they moved or thought about moving due to working from home possibilities, and results suggest these impacts still seem to be quite limited (see de Haas et al. [2022]). In addition, we did not calculate exact effects on accessibility and sustainability, although we expect those effects to be generally positive due to the decrease in peak travel and dampening effects on car travel. Fourth, this paper focused on the structural changes in working from home and teleconferencing due to the pandemic. There could be other potential structural effects of the COVID-19 pandemic on travel behaviour, such as changes in remote education, or a structural mode shift from public transport to car due to shifts in mode-related attitudes. When considering the overall effect of COVID-19 on travel behaviour, these effects also need to be considered. As time without COVID-measures goes on, it will become clearer to what extent these intentions of working people will become real behaviour. Of course, this could also be impacted by new policies by governments and employers, as well as other factors that affect travel behaviour.

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Appendix A. Papers included in literature overview

Authors	**Year**	**Country or Region**	**Method**
Balbontin et al.	2022	Australia	MDCEV
Beck et al.	2022	Australia	Descriptive analyses
Bohman et al.	2022	Sweden	Descriptive analyses
Campisi et al.	2021	Italy	Descriptive analyses
Ceccato et al.	2022	Italy	Discrete Choice Modelling
Christidis et al.	2022	Europe	Descriptive analyses and clustering
Christidis et al.	2021	Europe	Transport Model
Currie et al.	2021	Australia	Descriptive analyses
Javadinasr et al.	2022	United States	Descriptive Analyses
Kogus et al.	2022	Israel & Czechia	Descriptive analyses
Manser et al.	2022	Switzerland	Transport Model
Navaratman et al.	2022	Australia	Regression Modeling
Olde Kalter et al.	2021	The Netherlands	Regression Modeling
Paul & Taylor	2022	United States	Descriptive Analysis
Salon et al.	2022	United States	Descriptive Analysis
Ton et al.	2022	The Netherlands	Clustering
Currie et al.	2022	Australia	Descriptive Analysis
Downey et al.	2022	Scotland	Regression modelling
Xu et al.	2022	China	Spatiotemporal clustering
Sweet & Scott	2022	Canada	Descriptive analysis and regression modeling

Appendix B. Sample descriptives

Data source		**MPN**	**ODiN**
Population		People with gainful employment	The Netherlands
N		955	53 380
Age (years)	Mean	45	44
	Median	46	45
Gender (%)	Male (%)	50	50
Education (%)	Up to lower vocational school	16	24
	Secondary or lower tertiary degree	45	29
	Bachelors, Masters, or PhD	36	33
Urban Density (addresses/m^2)	0-500	9	8
	500-1000	20	22
	1000-1500	16	16
	1500-2500	32	30
	>2500	23	24
Household composition	Single	25	19
	Adults	45	30
	Adult(s) and children	29	51

Appendix C. Regression coefficients

Variable	Levels	Commute		Business	
		Estimate	Z-val.	Estimate	T-val.
Intercept		0.570***	4.34	1.784	0.350
Teleconferencing	No teleconferencing	Ref	-	Ref	-
	Equal or less often	0.036	0.474	-2.316	-1.24
	More often	0.056	0.297	-3.204	-0.723
	Much more often	-0.071	0.457	-12.1***	-3.40
Working from home	Not working from home	Ref	-	Ref	-
	Working less than 8h per week	-0.528***	-5.25	-0.818	-0.261
	Less than 6h increase	-0.004	-0.064	3.77	1.37
	6 to 13h increase	-0.230***	-3.28	-4.65*	-1.67
	14 to 20h increase	-0.438***	-5.71	-5.92***	-1.18
	21 to 28h increase	-0.757***	-5.71	-7.355*	-1.75
	More than 28h increase	-0.949***	-4.81	-18.779***	-3.27
Commute days before COVID		0.141***	10.3	0.314	0.369
Business travel before COVID		0.001***	2.83	0.766***	60.064
Change in hours worked per week		0.007***	3.26	0.219**	2.190
Urban density of municipality		0	0.198	0	0.92
Household composition	Single	Ref	-	Ref	-
	Adult	-0.098*	-1.95	1.75	0.879
	Youngest child <= 12	0.049	0.549	-3.36	-0.035
	Youngest child > 12	-0.080	-1.03	1.70	0.535
Number of children in household		0.007	0.166	3.69*	1.933
Age		0.002	1.09	-0.009	0.132
Gender	Man	Ref	-	Ref	-
	Woman	-0.012	-0.307	-0.054	-0.034
New job	Yes (ref: no)	0.034	0.605	-1.46	0.044
Changed days/time of work	Yes (ref: no)	-0.042	-0.700	-2.054	-0.171
Changed work location	Yes (ref: no)	-0.003	-0.051	-6.47**	-2.52
Changed education type	Yes (ref: no)	0.017	0.185	3.58	0.953
Child born in household	Yes (ref: no)	-0.010	-0.108	-3.22	-0.816
Death in household	Yes (ref: no)	-0.039	-0.212	-5.07	-0.800
Divorced or separated	Yes (ref: no)	0.228	1.355	5.061	0.687
Moved in together	Yes (ref: no)	-0.022	-0.153	7.51	1.34
Moved between 2019 and 2021		-0.004	-0.056	2.03	0.638
Someone from household moved	Yes (ref: no)	0.037	0.385	-6.64*	-1.69
Started a company	Yes (ref: no)	0.186	1.325	-10.1*	-1.66
New children moved in	Yes (ref: no)	0.004	0.013	-15.9	-1.38
New adults moved in	Yes (ref: no)	0.046	0.223	3.48	0.425
			*p<0.1; **p<0.05; ***p<0.01		