THE IMPACT OF VARIOUS FORMS OF FLEXIBLE WORKING ON MOBILITY AND CONGESTION ESTIMATED EMPIRICALLY

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Significance

1. INTRODUCTION

The various types of flexible working aim to render working more effective, efficient and pleasant for the organisation and its workers. Mobility patterns and road congestion are impacted if flexible working leads to more time and location independency for working. Possibilities for flexible working are enhanced by information and communication technologies. KiM distinguishes eight types of flexible working that impact mobility and road congestion:

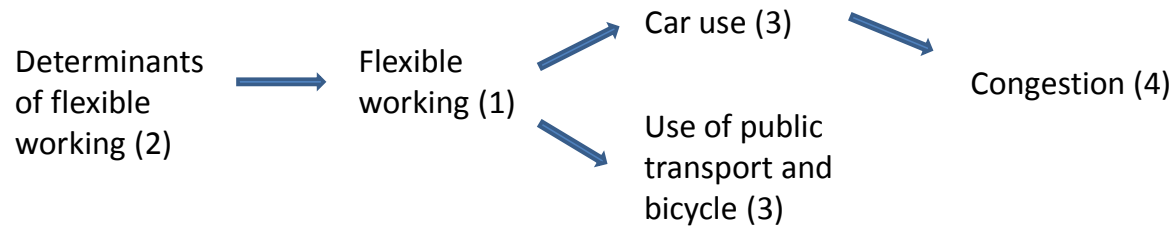
1. Working at home (instead of at other work addresses), excluding overtime (regular working at home was not considered as flexible working);
2. Avoiding car travel during peak periods by working at home and/or at other work locations on the same day;
3. Working at another company location;
4. Working at a flex office;
5. Shifting working hours at the regular working address (not working at home) to avoid car travel during peak periods;
6. Shifting working hours to avoid travelling on public transport during peak periods;
7. Avoiding car use for business trips;
8. Working during the trip while travelling on public transport.

The research questions are:

1. To what extent has flexible working developed in the Netherlands from 2000 to 2016?
2. How has the development of flexible working impacted the development of mobility by car and public transport, and congestion on the main trunk network (or national roads; especially highways)?

This research paper's method and results sections are structured according to four steps in Figure 1.

Figure 1. Structure of the paper.



2. METHOD

With regarding to working at home in the Netherlands, only the employees' mean hours per week were available in the *Nationale Enquete Arbeidsomstandigheden* (National Survey of Working Conditions) (NEA, 2017). No data for identifying other forms of flexible working, nor its impact on mobility and congestion, are available.

Flexible working arose in several countries (ATAC, 2005). In the USA, Alternate Work Schedules (AWA) comprise telecommuting, compressed work weeks and flexible working hours (Combs, 2010). In the Netherlands, a pilot estimation was made in 2007 of the level of telecommuting and its impacts on mobility (Ecorys, 2007), as based on surveys of 200 employees and statistics. In 2014, the KiM Netherlands Institute for Transport Policy Analysis conducted research aimed at identifying the opportunities and obstables of time- and place-independent work (KiM, 2014). Time- and place-independent work can be considered as the result of flexible working from the viewpoint of the field of transport. In the USA, estimations were made of the level of telecommuting (Mohktarian, et al, 2005), of the impact of telecommuting on vehicle miles travelled (0.8% or less) (Choo et al, 2002), and of the compensating impact of telecommuting on vehicle miles travelled by car use for other purposes (than home to work) by members of the household (Kim et al., 2015). In Belgium (TML, 2013), telecommuting's rebound effects were also estimated in a model study that found that approximately 70% of the reduction in car use could be compensated for by increased energy use at home, longer commuting distances, and induced traffic. Higher income earners seemingly telecommuted more frequently than low-income workers, but following similar patterns (He et al., 2014).

In order to identify the level and development of flexible working and its effects on mobility and congestion, KiM ordered surveys to be conducted in March 2014, 2015 and 2016, among 14,000 working people, using Telepanels. These surveys made it possible to identify and determine the extent to which flexible working developed from 2013-2015 (step 1), their determinants (step 2), the impact that flexible working had on the use of transport modes (car, public transport and bicycle) (step 3), and the routes avoided on the main trunk road network from 2013-2015 (step 4).

To acquire a representative sample, I&O Research derived a sample of 6,000 working people from the Panel Clix and Panel Inzicht Telepanels for March 2014, 2015 and 2016. This sample was drawn at random and stratified according to age, sex and region. After the first 6,000 respondents were attained, another sample was drawn of 8,000 working people who had indicated that they would engage in at least one of the four types of flexible working: types 1-5, as mentioned above, in which types 1 and 2 are combined. Further, for each type of flexible working, it was determined whether the respondent was a "starter", "stayer" or "stopper", and whether the person was an incidental or regular flexible worker. Using this two-stage sampling method, a sufficient number of workers were available with characteristics of flexible working to determine the impacts on mobility and congestion. Subsequently, all samples were weighed according to age, sex, region, education, sector, car use, and public transport use, as based on the OViN, the mobility survey of Statistics Netherlands, which was weighed according to statistics pertaining to age, sex, household size, region, urbanisation, province, household income, and ownership of cars and bicycles.

Questions were asked to determine on which days and hours the workers worked at home, at another location or flex office, or had shifted working times to avoid peak hour travel (7:00-9:00; 16:00-18:00) (step 1). For each working day of a recent representative week, the respondents had to specify how many hours they had worked at their regular working place, at home, at another location of their company, in a flex office or externally (e.g. meetings, courses). People who had no fixed day(s) for working at a location other than their regular working address, or did so less than once a week, were asked to indicate the frequency. Finally, people who shifted working times to avoid car use during peak hours were asked how often per week they did this, for which peak hours (morning and/or evening peak), and on what weekday(s). All retrieved values were converted to a frequency for each day of the working week (e.g. someone who works solely at home on Friday's, and once every two weeks, has a Friday frequency for working at home of ½, and 0 for Monday-Thursday in an average week. (In cases not involving a fixed day, the average frequency is 1/10 for each day, etc.). Moreover, the use of transport modes was determined on days that workers travel to their regular working address, to another location or to a flex office, as were the modes they would have used instead had they travelled to their regular working address (for step 3). Further, the routes on the national roads they (would have) travelled on by car were determined (for step 4). When people do not use their cars on a certain day to commute (e.g. they work at home instead), it was determined if other members of the household had used their cars on those days. All mobility data were summated, extrapolated and scaled up to determine the (nationwide) totals for 2013, 2014 and 2015.

The impacts of determinants for engaging in at least one type of flexible working (step 2) were analysed, using a logistic regression at micro level on 81 impact factors, as based on the survey data.

The impact of flexible working on car and public transport use from 2013 to 2015 was determined by registering the changes that flexible working caused in the use of transport modes during each of the two consecutive years that the person participated in the Telepanel. Approximately half of the 2015 sample also participated in the 2014 survey, while about half of the 2016 sample also participated in the 2015 survey. Approximately one-third of the respondents in the 2016 sample participated in all three surveys.

Based on the survey, the development of working at home (types 1 and 2) from 2013- 2015 was extrapolated to 2000-2016, using statistical data (mean hours per week from the National Survey of Working Conditions and number of jobs). How working at home impacted the use of transport modes from 2013-2015 (step 3) was extrapolated to 2000-2016 based on the impacts assessed during the period 2013-2015, the extrapolated development of working at home, and the developments of kilometres per transport mode and of the distance to work, according to OViN. In order to identify the development of shifting work hours to avoid peak hour travel (type 5), the first step involved estimating the number of these shifts per week for 23,000 workers from 2013-2015, using a logistic analysis at the micro level that included such characteristics as the possibility of flexible work hours, sector, hours per week, distance to work, congestion and amount of traffic commuting to work, vehicle type, and region. In a second step, the impacts of the key factors (possibility of flexible work hours, sector, working hours, distance to work and congestion),

estimated as elasticities, were multiplied with the national statistics pertaining to these factors, in order to determine how the number of shifts per week and of workers per year had developed. This model was first used to determine the number of times people avoided peak hours during the years 2000-2016. Further, the impact that shifting working hours had on transport mode use was determined by multiplying the level of shifting and the impact of shifting, as estimated using the 2013-2015 survey, while controlling for the development of distance to work. As no historical information was available for the development of working at a company's other location or in a flex office (types 3 and 4), type 3 was therefore assumed to follow the development of working at home 2000-2016; that is, similar to type 1 (working at home), working at a company's other location would have already existed prior to the year 2000. Type 4 was assumed to follow the development of telecommuting, because, like telecommuting, working at flex offices was virtually inexistent in 2000 and was facilitated by the emergence of internet services.

To assess the impact of flexible working (types 1-5; 1 and 2 were combined) on congestion (step 4), firstly, surveys were used to determine the impact on changes in the use of the main trunk road network 2013-2015. Second, the changes in trips 2013-2015 on the main trunk road network were converted to intensities per stretch (data for approximately 3,000 stretches are available), per (normal) day of the week, per year and per period of the day (00:00-06:00, 06:00-07:00, 07:00-09:00, 09:00-10:00, 10:00-15:00, 15:00-16:00,16:00-18:00, 18:00-19:00, 19:00-24:00). Thirdly, to identify the impact on congestion (in terms of the hours of delay), a regression based method was used that KiM had developed previously for explaining trends in congestion, as based on traffic amounts in vehicle kilometres, accidents, road works, weather, and policy measures (Van der Loop et al, 2014, 2016). A regression analysis 2000-2016 was done per period of the day. The coefficients resulting from the regression were multiplied by the developments in the explanatory variables and related to the number of hours of delay in the base year (2000). To identify the impact of flexible working, two variants were calculated: one with the impact of the observed, actual traffic amount (including the impact of flexible working), and the other with the traffic amount that would have occurred without flexible working, as based on the intensities and routes measured in surveys. The difference between these two effects is the impact of flexible working 2013-2015.

To extent the analysis of the impact of flexible working on traffic congestion to the period 2000-2016, elasticities were estimated of the changes in traffic amount and hours of delay as a consequence of changes in flexible working. These elasticities were based on the impacts of flexible working for 2013-2015, as described above. Moreover, these elasticities were estimated for three time periods (7:00-9:00; 16:00-18:00; and rest of the day), for four regions (North of the Randstad, South of the Randstad, Noord-Brabant, and rest of the country), and for each of the four types of flexible working. The impact that the four types of flexible working had on traffic amount and hours of delay was determined by multiplying the development of these types from 2000-2016 with the elasticities.

The results of this method for determining the impact of flexible working on the hours of delay was checked and found to be consistent with the average ratio that generally exists between the increase of traffic and the increase of hours of delay on national roads in the Netherlands from 2000-2016.

3. DEVELOPMENTS IN FLEXIBLE WORKING

The overview of types of flexible working in Table 1 reveals that working at home, instead of at another regular location, and shifting work hours to avoid peak hours, had the highest occurrences in 2016, and were moreover often combined in a single day (8.6%). Not all workers who work at home avoided travelling by car during the peak hours (12.6%).

Working at a company's other locations and at a flex office occurred less frequently than working at home and shifting working hours to avoid travelling by car during peak hours. Regular working at home was not considered as flexible working.

Table 1. All eight types of flexible working in the Netherlands 2014-2016.

	Share of workers (%)		
	2014	**2015**	**2016**
Types of working at home or at another location			
0) Working at home (at home is work address)(no flexible working)	6.4	6.1	6.0
1) a) Working at home (instead of other working address) and avoiding peak hour travel by car	16.9	17.4	17.5
b) Working at home (instead of other working address) without avoiding peak hour travel by car (usually using the car during non-peak hours or using another mode)	12.1	12.5	12.6
2) Avoiding peak hour travel by car by working at home and other address on the same day	8.1	8.5	8.6
3) Working at another location of the company	1.1	1.0	1.0
4) Working at a flex office	5.3	6.2	6.2
Shifting working hours			
5) Shifting working hours at working address (not working at home) to avoid peak hour travel by car	10.3	10.9	11.2
6) Shifting working hours to avoid peak hour travel by public transport	4.1	4.9	5.0
Other forms of flexible working			
7) Avoid car use for business trips	1.4	1.2	1.2
8) Working during the trip in public transport	Unknown	7.8	7.8

Of all the workers in the Netherlands in 2016, 84% were employees, 12% were independent contractors without employees, and 4% were independent contractors with employees. Independent contractors more often worked at home and shifted working hours to avoid peak hour travel by car than employees (Table 2). Moreover, employees worked on average fewer days per week at home than independent contractors, although the number of days per week that they shifted working hours to avoid peak hour travel by car were about qual. The number of days people work at home indicated in Table 2, consist partly (about half) of working full days and for the rest of working only a part of the day at home. From the workers avoiding peak hours by car by shifting work hours, approximately 50% usually only avoids the morning peak, 20% only the evening peak and 30% both.

Table 2. Patterns in flexible working (types 1-5) in 2015 in the Netherlands

	Employees (84%)	**Independent contractor without employees** (12%)	**Independent contractor with employees** (4%)	**Total**
Share in type of worker				
Share working at home	32%	74%	68%	32%
Share avoiding peak hour travel	10%	14%	28%	11%
Days per week working at home	1.3	2.5	2.6	1.6
Days per week avoiding peak hour travel	2.7	2.4	2.6	2.6
Share of all workers				
Days per week working at home	1.3	2.5	2.6	1.6
Days per week avoiding peak	0.3	0.3	0.7	0.3

The amount of flexible working differs between the days of the week, but these differences generally are not very large (Figure 2). Working at home occurs more often than shifting working hours to avoid peak hour travel by car.

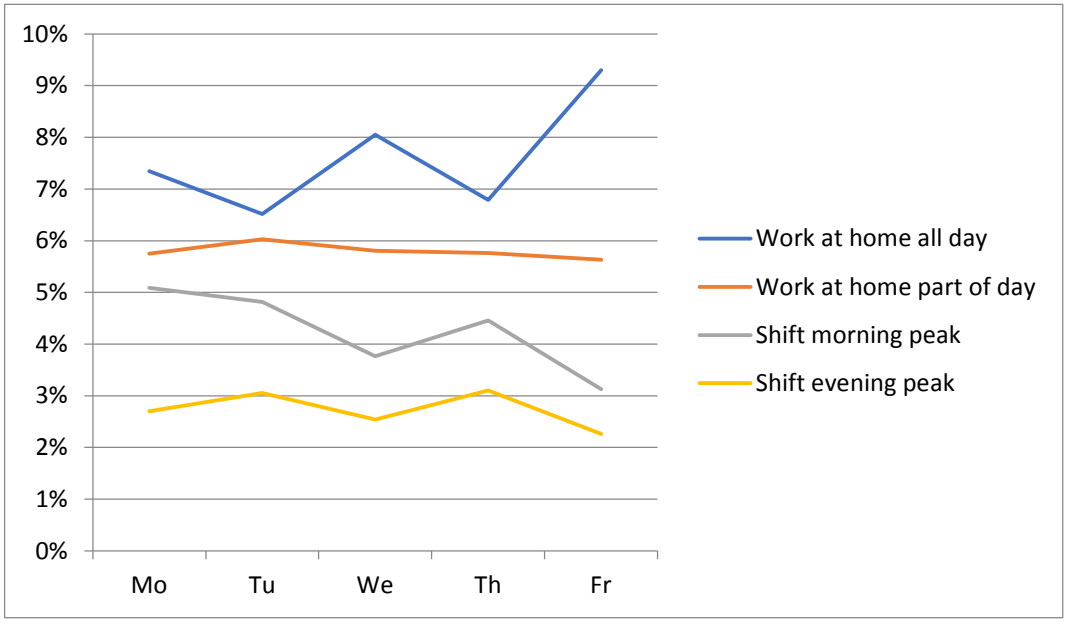


Figure 2. Share of workers engaging in flexible working (types 1-5) per weekday in the Netherlands in 2016

The share of workers engaged in flexible working, and with working conditions that render it possible to do so, differs according to employment sector (Table 3). In sectors with the highest share of flexible working, there is a relatively low share of workers who, owing to their working conditions, do not have the possibility of flexible working. Consequently, the share of workers with opportunities for engaging in flexible working appears – in most sectors - to be approximately 20%.

Table 3. Share of workers per sector who work at home, shift working hours, and have the working conditions for possibly working at home or shifting working hours, in the Netherlands in 2015.

	Industry	Construction industry	Utilities companies	Commerce	Catering	Transport	ICT	Financial services	Business services	Public administration	Education	Health and welfare	Total
Working at home													
Works at home	22%	28%	61%	28%	23%	19%	65%	57%	62%	65%	39%	30%	39%
Not possible	56%	44%	21%	48%	59%	63%	12%	17%	18%	17%	48%	56%	41%
Possible	22%	27%	18%	24%	18%	18%	23%	26%	20%	18%	14%	14%	20%
Shifting working hours to avoid using cars during peak hours													
Avoids peak travel by car	11%	16%	21%	8%	5%	9%	20%	13%	19%	12%	6%	6%	11%
Does not use car	18%	14%	22%	30%	32%	23%	27%	32%	33%	44%	36%	31%	30%
Cannot avoid	45%	43%	17%	41%	41%	53%	17%	20%	19%	12%	35%	46%	34%
Can avoid peak by car	26%	28%	39%	22%	22%	15%	36%	35%	30%	32%	22%	18%	25%

The number of hours that employees work at home instead of at another location increased from 10.1 million hours per week in 2000, to 13.9 million hours per week in 2016 (+38%). The amount of peak avoidances by workers increased from 1.7 million in 2000, to 2.4 million per week in 2016 (+40%).

4. DETERMINANTS OF FLEXIBLE WORKING

Based on a logistic regression, on data of the March 2014 sample, the influence of 43 of the 81 determinants on flexible working (types 1-5 in Table 1) appeared to be statistically significant (Table 4). The possibilities of flexible working as a working condition (5 variables) and type of work (employer, independent contractor with or without employees) appeared to be most important. Sector (14 variables), number of working hours per week (4 variables), congestion to or from work (6 variables), and distance from home to work (4 variables) often appeared to be significant for flexible working. Some variables of personal characteristics (17 variables), commuting arrangements (13 variables), type of car (one car, one or more lease cars in household) and company size (4 variables) appeared to be significant. No significance occurred between regions (7 variables).

Table 4. Significant (< 0.05) results of a logistic regression of types of flexible working (FW) by 81 determinants in the Netherlands in 2014

Type of determinant	**Determinant**	B	Sig.
Possibilities of FW	Permission to work at home	1.409	.000
Possibilities of FW	External access to files and programs	.854	.000
Type of worker	Independent contractor without employees	1.651	.000
Possibilities of FW	External access to e-mail	.596	.000
Sector	ICT	.785	.000
Possibilities of FW	Possibility to use flex office	.661	.000
Type of worker	Independent contractor with employees	1.189	.000
Possibilities of FW	Other possibility to work at home or elsewhere	1.064	.000
Sector	Financial services	.648	.000
Sector	Public administration	.878	.000
Working hours	Working hours 36-40 per week	-.650	.000
Congestion	Congestion from work to home: sometimes	.403	.000
Personal characteristics	Income >60,000 euro	.362	.000
Congestion	Congestion from work to home: often	.564	.000
Commuting arrangements	Reimbursement for car use	-.244	.000
Commuting arrangements	Bike services at work location	-.338	.000
Sector	Business services	.439	.000
Commuting distance	Home to work 50-100 km	.359	.000
Working hours	Working hours 12-23 hours	-.476	.000
Personal characteristics	Higher professional education or university	.802	.000
Congestion	Congestion from work to home: (almost) always	.557	.000
Commuting arrangements	Reimbursement for public transport	-.192	.000
Working hours	Working hours 24-35 per week	-.409	.001
Personal characteristics	Household with children	.235	.001
Congestion	Congestion to work: often	.362	.001
Commuting arrangements	Free parking at employment location	-.166	.001
Congestion	Congestion to work: (almost) always	.446	.002
Sector	Construction industry	.358	.003
Sector	Other services	.317	.003
Sector	Utilities	.548	.003
Commuting arrangements	Paid parking at work location	.311	.005
Sector	Culture	.699	.005
Commuting distance	Home to work 7.6-15 km	-.180	.005
Personal characteristics	< 25 years old	.226	.015
Company size	11-50 employees	-.217	.017
Sector	Education	.253	.019
Commuting arrangements	Reimbursement for bike use	-.147	.023
Car ownership	1 lease car in household	.153	.025
Working hours	Working hours >40 hours per week	-.299	.034
Personal characteristics	1 person working in household	-.123	.041
Commuting arrangements	Business travel pass for free public transport	.210	.041
Personal characteristics	Other type of education	.544	.047
Congestion	Congestion home to work: sometimes	.154	.049
Constant	Constant	-1.715	.000

5. EFFECTS FLEXIBLE WORKING ON CAR AND PUBLIC TRANSPORT USE

From 2000 to 2016, all types of flexible working in the Netherlands collectively accounted for a 2% reduction in car kilometres on working days, and a 7% reduction during peak hours (7:00-9:00; 16:00-18:00) on all roads (national, regional and municipal). The reduction of public transport kilometres was 2% on working days, and 2% during peak hours.

Owing to the increase in flexible working, the amount of vehicle kilometres for commuting on all roads in the Netherlands during peak hours did not increase from 16 billion kms in 2000 to 25 billion in 2016, but rather only from 12 billion to 17 billion kms, respectively (Figure 3). The yearly effect of flexible working increased by 21% (from 27% in 2000, to 32% in 2016). Working at home and avoiding peak hour travel had the largest effects (31% and 64%, respectively).

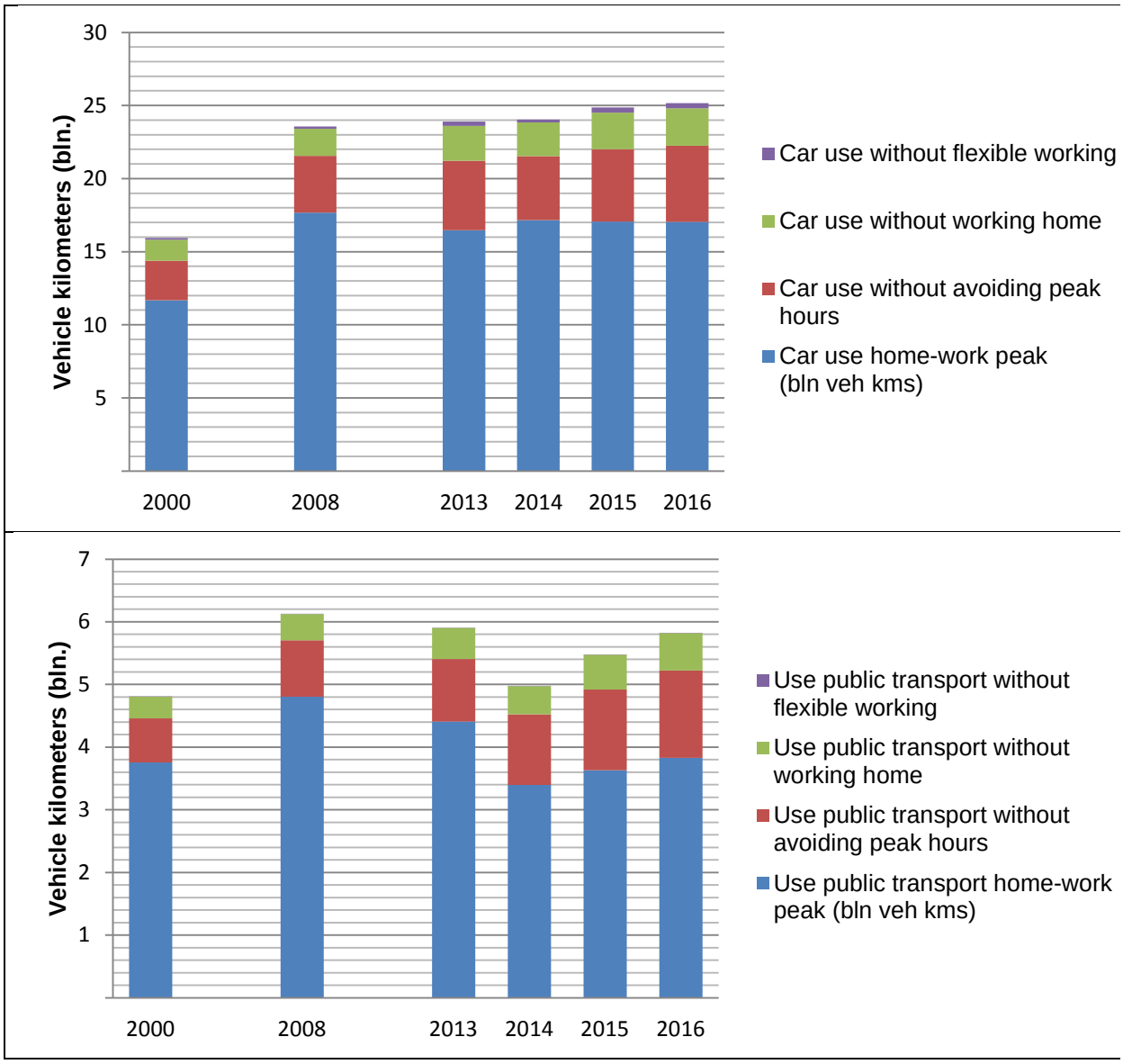


Figure 3. Impact of flexible working on use of cars and public transport for home to work commutes during peak hours (7:00-9:00; 16:00-18:00)

The impact of shifting working hours to avoid using cars during peak hours is larger than the impact of working at home. The reason for this is that not all people who work at home instead of at their other working address routinely use cars (68% routinely use cars during 77% of the days), or do so during the peak hours (58% use cars during peak hours). Consequently, car use during peak hours was only actually avoided on 31% of the days spent working at home. Additionally, workers shifting working hours to avoid car use during peak hours did so during on average more days per week than workers working at home in stead of their regular work address (Table 2). Further, workers shifting working hours travel longer distances to work (38 km vs. 28 km for people who work at home) and have a relatively high share of use of the national road network (90% vs. 75% use of the national road network; 51% vs. 39% every day).

Shifting working hours to avoid car use during peak hours only occurs if these workers are able to choose their working hours. Some 80% of this group indicated that avoiding congestion was one of the reasons for their choice to avoid peak hour travel; moreover, the more years that they had already avoided peak hour travel, the more often they seemingly mentioned avoidance of congestion as a reason, which supports the conclusion that avoidance of peak hour travel had already been impacting car use for several years.

Without the increase in flexible working, the use of public transport for commuting in the Netherlands during peak hours would have increased from 4.8 billion kms in 2000 to 5.8 billion in 2016. Owing to flexible working, in 2016 public transport use remained at the same level it was in 2000 (approx. 3.8 billion kms). Working at home and avoiding peak hours had the largest effects (30% and 70%, respectively).

Flexible working can also have an impact on car use for business purposes, because, for example, workers might choose a location for conferencing that is situated close to their home address, instead of at the office of the inviting company. The impact of flexible working on car use for business purposes was estimated to be at maximum 0.25% of the 2 billion car kilometres devoted to business purposes on all roads in the Netherlands in 2016. This impact is small in comparison to the impact that flexible working had on car use for commuting purposes. The estimation of 0.25% derives from the fact that 11% of the respondents stated that they made 25% fewer business trips during peak hours, which can be related to flexible working in 9% of the cases.

6. IMPACTS OF FLEXIBLE WORKING ON ROAD CONGESTION

Without flexible working, the amount of traffic (in vehicle kilometres) on national roads (highways) in the Netherlands during the period 2000-2016 would have increased by 29%, instead of 23% (an impact of 2.5% for flexible working) (Figure 8). Without flexible working, hours of delay (in vehicle hours, with reference to 100 km/h) would have increased by 52%, instead of 39% (an impact of 13% for flexible working). Working at home (-9%) had the largest impact on congestion avoidance during the entire day (Figure 2). During peak hours, peak hour travel avoidance had the largest impact.

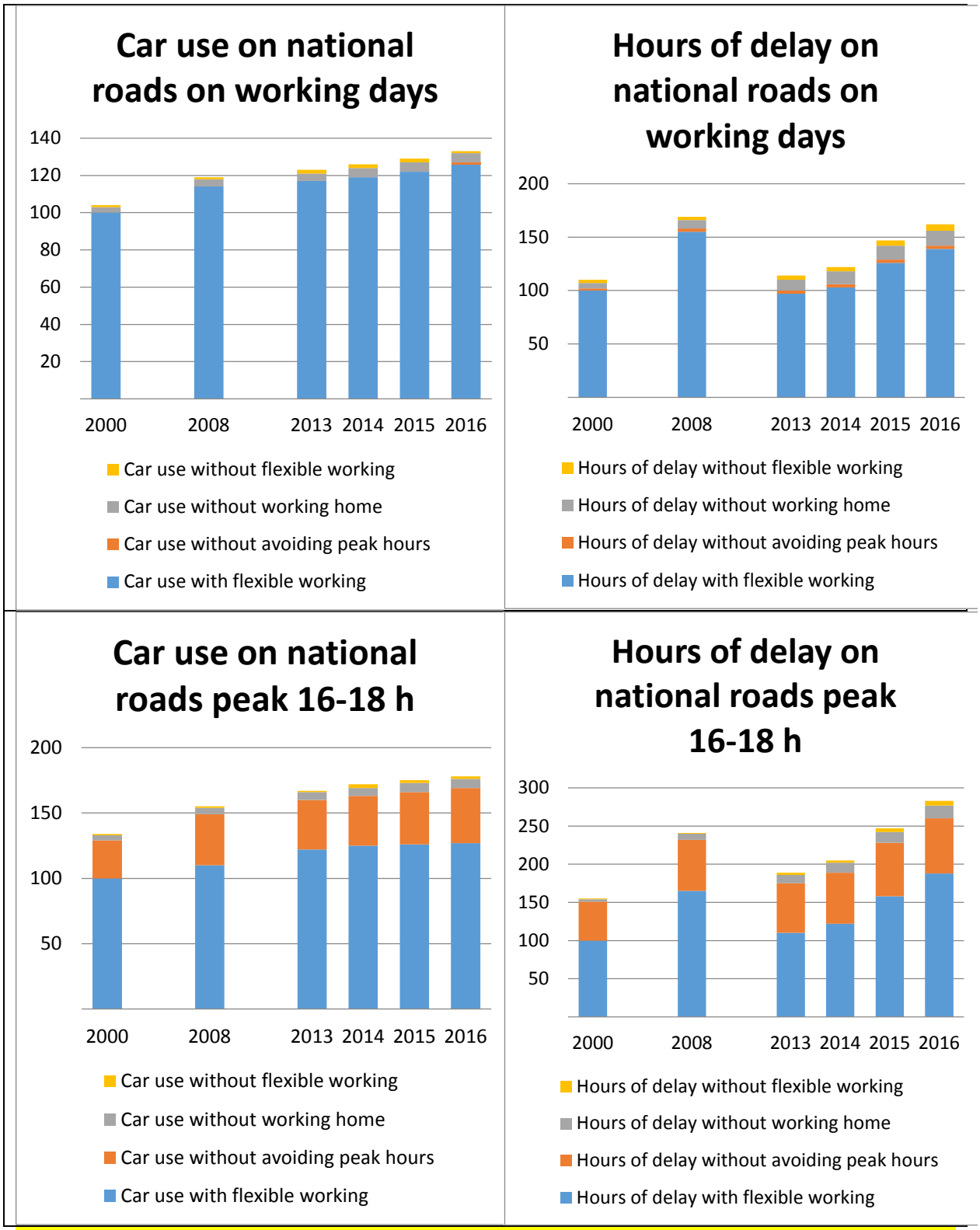


Figure 4. Impact of flexible working on car use (vehicle kms) and hours of delay on national roads in the Netherlands 2000-2016, on working days and during peak hours 16:00-18:00.

From 2000 to 2008, the impact of shifting working hours increased significantly, which can be explained by the increase in congestion during that period. From 2008 to 2013, the impact of shifting working hours remained at the same level. From 2013 to 2016, the impact of shifting working hours increased again, similar to the level of congestion. From 2013 to 2016, policy measures also contributed to reducing congestion by, for example, offering financial rewards for peak avoidance (Van der Loop et al, 2017). The reasons why shifting working hours has more impact on mobility than working at home (see the previous paragraph) also apply here. The impact that shifting working hours to avoid peak hour car use has on hours of delay appears to be largely compensated for by the increase in hours of delay during off peak hours, which is likely due to the fact that shifting primarily occurs on congested roads, and because congestion during the hours before and after the peak hours is partly caused by avoiding the peak hours.

On a normal weekday in 2016, on average some 150,000 fewer passenger cars travel during the morning peak (7:00-9:00) on national roads in the Netherlands as a consequence of flexible working. During the afternoon peak, that figure is around 100,000 fewer cars. During the off peak hours there are some 200,000 more cars (especially due to those people shifting working hours to avoid peak hour car travel). The effects are slightly larger on Mondays and Thursdays, and smaller on Wednesdays and Fridays.

There were no major regional differences in the development of flexible working in the Netherlands from 2013 to 2015. However, owing to differing levels of congestion per region, the impact on congestion does differ between regions. Flexible working had the largest impact on congestion on the national roads surrounding Amsterdam and Utrecht.

7. DISCUSSION

This study revealed that it is indeed possible to use survey data, statistics and traffic data to empirically identify the level and development of flexible working, as well as its impacts on mobility and traffic congestion. In order to develop this method, rather complex and time-consuming statistical analyses were required. The data requirements are also high, as sufficient coverage of the working population and the road network is necessary. This study does show that with these data and analyses useful insights can be obtained in the role of flexible working for the historical trends in mobility and road congestion.

This study demonstrates that flexible working has played an important role in reducing the growth of car-use and congestion, especially during the peak hours. Similar results hold for public transport.

The levels and development of several types of flexible working can seemingly serve as starting points for policy initiatives that render flexible working effective for social purposes. Moreover, as a means of further improving working conditions, it is expected that employer and employee organisations might benefit from these results. Increased congestion does also increase the need to avoid home-to-work travel during the peak hours or entirely; both governments and organisations of employers and employees play a role in this.

Until now, empirical research of flexible working patterns in relation with transport appears to be rather limited to certain aspects. Especially, commuters reactions to traffic congestion by shifting working hours appear to be an important factor in traffic congestion, but were not measured thus far. Also, only very little empirical research was available pertaining to the influences of types of flexible working on mobility and traffic congestion.

In this paper, the researchers strove to publish their results in a manner that allowed for their potential use by other countries than the Netherlands; that is, the results were presented in entities that allow for comparison with other data and studies. It would be interesting to see how the impact of flexible working has evolved in different situations. Empirical evidence from countries other than The Netherlands remains scarce and therefore, as far as the researchers could find, no comparable data are available yet.

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