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Telework and the limited impact on traffic reduction – Case study Madrid (Spain)

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Abstract: Teleworking has been proposed by organizations and policymakers as a key strategy to help reduce the number of commutes and boost employee satisfaction. Since telework may be linked to a tool to reduce traffic in urban areas, this research aims to determine the impact that telework has on traffic congestion in Madrid (Spain), given a post-Covid19 context in which many organizations have implemented teleworking in the long term. This study provides evidence that teleworking has had a limited favourable impact on traffic in the city of Madrid based on the correlation between telework implementation and the traffic data collected from 7.365 traffic sensors located in Madrid that are distributed and managed by the Madrid City Council. Covid19 represents an influx point with regard to telework implementation, allowing this kind of research to interpret the answer to the question. The results of our research, through regression calculations and Pearson's correlation coefficient, show that telework in the city of Madrid does not generate a positive impact on traffic during peak times proportional to the increase of telework, as expected based on the existing literature. However, there are other elements that influence the modal choice that may affect this correlation, considering that teleworking allows people greater residence flexibility and that residence location and distance to the workplace are factors that significantly influence the modal choice of transport.

1 Introduction

Home-based telework, also known as teleworking, a labour methodology that allows employees to work from home to the extent the job allows, emerged two decades ago from developments in information and communication technologies (ICT). The number of workers who could potentially work from home has grown over the years and due to the Covid19, this labour methodology has become firmly established [1,2].

Telework has led to a paradigm shift in urban mobility, given that the main purpose of transit in urban environments is commuting [3-5]. The fact that residents can work from home contributes to a reduction in the number of commuters in absolute terms [6,7] and can prompt a significant change in urban mobility. Telework represents an opportunity to improve environmental sustainability [8], as it is an efficient and sustainable measure that is viewed favourably by consumers since it does not imply a significant cost and provides indirect benefits in terms of economic savings and work/life balance [9].

Thus, this phenomenon has prompted an increase in the number of studies and research evaluating the effect that the telework has on urban traffic since it may help reduce commuters. Some studies suggest there is a positive impacts [10-12], while others conclude differently suggesting telework has no clear impact on traffic improvement [13]. The different research methodologies and various geographies studied may explain the varying points of view. Also, several studies point out the impact that telework may have on home location [14] and the resulting effect on the mobility patterns and transport behaviour for the employees who work from home. Teleworkers tend to have longer commute distances than others [15-17] which impacts travel patterns with regards to means of transport and vehicle use. The impact that telework may have on travel patterns is influenced by other factors such as frequency of days working from home [7], commute distance [12,18,19] and commute travel time [20,21].

This research aims to provide an exhaustive literature review and a make new contribution to the impact of telework on traffic by analyzing the evolution of congestion in the city of Madrid during peak times in correlation with the establishment of telework to determine the relationship in between both variables, based on information provided by the Madrid Council and gathered from 7.360 traffic sensors throughout the city.

The analysis is carried out specifically in the city of Madrid (Spain). As the sixth most populace region in Europe [22] and the third most populace metropolitan area in Europe [23], there is a high percentage of organizations that have implemented telework [5,24] and an equally high percentage of white-collar workers. In addition, Madrid has a series of environmental characteristics—cultural, labour-related, economic, climatological, educational, etc.—that influence the choice of means of transport [25].

Since Covid19 helped telework globally, this research aims to offer new evidence from Madrid after pandemic disruption compared to the literature published prior to Covid19 when the teleworking situation was significantly different. The justification for the study lies in the fact that telework represents a paradigm shift within organizations and for urban mobility given that this type of work-related travel accounts for a high proportion of aggregate travel and, above all, the change that telework exerts on the lifestyle of residents, significantly influencing means of transport choice for commutes.

2 Literature review: impact of telework on urban mobility and traffic

2.1 Mobility and teleworking patterns of Madrid city

The city of Madrid is the sixth most populace region in Europe with 6.62 million inhabitants[22]. According to the most recent survey on Madrid's population mobility [26], there are roughly 15,847,266 daily commutes within the region, while in the city's local area, the number of trips amounts to 7,728,000. Taking into account suburban Madrid, given its proximity, the number of daily trips totals 14,680,000. Twenty-seven percent of daily trips are work-related. Excluding walking trips, the percentage of daily work-related commutes rises to 36.7%. Likewise, of these total commutes, 58.9% are made using private vehicles, while the remaining 41.1% use public transport. These figures show a high percentage of private vehicle usage for work-related trips among Madrid residents, which poses a challenge for transportation authorities to plan and scale the urban infrastructure, while at the same time encouraging the use of public transport. Madrid has an extensive public transport system, with the second most extensive metro in Europe (after London [27]). Therefore, public transport providers must keep working to increase public transport usage rates.

Due to the Covid pandemic and the corresponding healthcare measures implemented, companies were forced to adopt teleworking systems in light of the restrictions imposed by public administrations, which led to an increase in the percentage of teleworkers in the European Union, from 15% in 2018 to 25% in 2020 [28]. In 2019, only 8% of employed residents in Madrid were teleworking [5], while as of September 2022, this figure rose to 23% [5, 24, 29]. It is important to note that the type of telework offered differs from one company to another, according to logistics, and organizational and operational needs; for example, remote work can be carried out full-time or part-time on weekly basis. In 2021, Madrid's 3.2 million telecommuters averaged 3.5 remote working days per week [30].

2.2 Impact of telework on urban mobility and traffic

Mobility in urban environments depends on the means of transport chosen for the journey. The choice of means of transport depends on various cultural [31] and environmental factors [32], but especially on the motivation for the trip [33]. In Europe, most travel in urban environments is work-related [4], so any attempt to make this type of travel more sustainable will achieve significant improvement ratios [34].

Teleworking, also known as telecommuting, is a way to perform one's professional activity remotely from a distance. This form of work, primarily concentrated among (white-collar) jobs with the operational flexibility to allow it, was developed in the 1980s [35,36], though the first studies adapted to a regulated and recognized form of work performance did not emerge until the 1990s [37]. [36] provide the most complete definition: "a flexible work arrangement whereby workers work in locations, remote from their central offices or production facilities, with no personal contact with co-workers, but the ability to communicate with co-workers using ICT".

COVID-19 brought about a paradigm shift in the labour markets of different world economies [38,39]. The paralysis of activity and suspension of mobility forced many organizations to implement the technology necessary to carry out activity remotely. Once the health crisis subsided, organizations consolidated the model, permitting much telework to remain permanent [1]. The cessation of activity and mobility restrictions caused a major reduction of mobility in all areas, both urban and interurban [40-42]. This reduction in the mobility of people and vehicles resulted in a drastic decline in greenhouse gas emission levels [43,44]. However, other studies claim that there was an increase in private car use as a result of COVID-19 for safety reasons; these studies predict that public transport use will return to pre-pandemic levels in the future [45].

Some of the existing literature suggests that telework potentially represents a chance to drastically reduce the number of trips, thus reducing traffic [10-12] but other studies suggest that the benefits of telecommuting are significantly less than anticipated [13].

With regard to the impact of telework on urban mobility, there is ample literature that strives to determine whether telework has a positive or limited impact on traffic. The first studies appeared back in the 1990s, when it was suggested that working from home would help cut traffic in urban areas by reducing the number of trips and distances for people working from home [46-49]. However, some contributions suggested that the aggregate travel impact will remain relatively flat in the future, even if telecommuting increased considerably [50]. In the last couple of decades, some studies has addressed the question of whether teleworking affects urban mobility positively, negatively, or in a limited way.

Several studies suggest that commute distance represents an important factor in travel behaviour. Commute distances for telecommuters, as an aggregate, are lower than distances for non-teleworkers, given the reduction in the number of commutes [16,51]. However, more recent research concludes that teleworkers, commute further on a weekly basis regardless of the fact that the number of commutes is reduced [52]. Telecommuting also increases total daily trip rates for both telecommuters and their households [53].

However, it is important to consider that telecommuting is a major factor in residential location decisions [54], meaning that the distances covered can be influenced by the household's decision since telework allows workers to move their homes further from the office, given the reduction of commute frequency. However, there is no clear evidence of the impact that telework may have on home location choice [55,56]. On the other hand, residence location may trigger the decision to telework [57]. [58] conclude that telecommuters tend to choose lifestyles involving longer one-way commutes, longer daily work trips, and longer daily non-work trips than non-telecommuters, as a result of the residential location being further from the office. In fact, teleworkers are willing to accept longer – albeit lees frequent - commutes [21] . Telework may weaken the relationship between the current urban structure and travel patterns prompting a redrafting of the policies to adapt the urban structures to an increasingly widespread telework context [59].

It is important to point that the travel patterns shown by teleworkers are also studied based on the effect that telework has on both work trips and non-work trips. Teleworkers tend to cover further distances daily for non-work trips [18,60], and clock a higher number of non-work trips [13,61-64].

Teleworkers also show relevant patterns in relation to modal choice and its consequent impact on traffic. Some studies indicate that telework may allow a significant aggregated reduction of car use [10,65] in miles. In fact, telework may contribute both to the shifting away from automobile dependency to sustainable travel [66], to the use of active transport modes [12] and to the increased use of non-motorized travel [67,68]. Moreover, certain literature suggests that teleworkers modal choice patterns tend toward more pollutant transport modes [69], including cars [70]. The higher is the telework frequency , the higher the private car use [19].

The International Labor Office (ILO) classifies telework as three types; regular telework at home, highly mobile telework ("at several locations regularly, with a high level of mobility") and occasional telework ("at one or more locations outside the employer's premises only occasionally") [71]. But there are also studies that suggest distinct travel patterns based on two types of daily telework: partial-day teleworking and full-day teleworking. Partial-day teleworkers significantly increase the number of trips and travel further while full-day teleworkers, on the days they engage in telework, make significantly fewer and shorter trips and are less likely to drive a car compared to those who do not telework [12]. [72], through a hazard model, determines that part-day teleworkers tend to commute during midday intervals avoiding peak-hours.

The majority of the literature agrees that it is possible to obtain positive results reducing peak-hour trips and vehicle miles travelled, through telework [11,20,68]. Avoiding peak-hours is directly correlated to flexibility at work. One of the main drivers for teleworkers is the possibility of avoiding peak traffic hours [73].

The literature review has been based on a comprehensive examination of the Web of Science database, where 53 articles have been identified as the most relevant to this question. Of the 53 articles, 44 of them, 83%), are studies based pre-Covid19 circumstances when the worldwide telework rate was far lower than post-Covid19. This means that there is lack of contributions in the current scenario where teleworking is much more prominent.

3 Methodology

Based on a review of the literature, since telework is understood as a measure that could improve traffic by reducing commutes, the data indicates the effect is limited or null. In this respect, this research aims to analyze how telework impacts urban traffic in the city of Madrid, according to the methodology described in this section.

First, we must determine the evolution of the telework rate over the years [5,24,29] and traffic occupancy in Madrid, using aggregated figures from the Madrid City Council database centre [74], and introducing timeframes to determine peak and off-peak times. This previous data organization allows the subsequent correlation an d regression analysis to detect dependencies between telework and traffic occupancy in Madrid city.

Using regression analysis, we analyze the relationship between telework and Madrid traffic during peak times The dependent variable, peak time traffic in Madrid, is denoted as Y, while the independent variable, telework implementation in Madrid is denoted X. There is always an accepted margin error since the variables will never correlate perfectly. The variation from the regression line can be split in two parts: explained variation, which is accounted for by the independent variable, and unexplained variation, which is not accounted for by the independent variable. Thus, part of the change in variable is due to another variable that we set as hypothesis, and part is due to other factors as indicated in the literature review.

In regression analysis, we seek to determine if the relationship pattern between two variable values can be described as a straight line (1), which is the simplest and most used form.

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$$Y = a + bX \quad (1)$$

where:

Y is the dependent variable, measured in units of the dependent variable, X is the independent variable, measured in units of the independent variable, and a and b are constants defining the nature of the relationship between the variables X and Y.

a or Y-intercept (also known as Yint) represents the value of Y when X = 0.

b represents the incline of the line known as the regression coefficient and is the change in Y associated with a one-unit change in X. The greater the regression coefficient, the more influence the independent variable has on the dependent variable, and the more change in Y associated with a change in X.

The regression coefficient represents a good choice to check the effect of the telework variable to the traffic variable from a policy researcher perspective. To quantify the strength and direction of the relationship between two variables, we use the linear correlation coefficient (2):

$$r = \frac{\sum \frac{(x_i - \bar{x})}{s_x} \frac{(y_i - y)}{s_y}}{n-1} \quad (2)$$

where:

$\bar{x}$ and s_x are the sample mean and sample standard deviation of x, and $\bar{y}$ and s_y are the mean and standard deviation of the y,

n is the sample size.

This statistic numerically describes how strong the straight-line or linear relationship is between the two variables and the direction, positive or negative.

ANOVA analysis is also used to partition the variation using sums of squares. The sums of squares and mean sums of squares are commonly presented in the regression analysis of variance table. The ratio of the mean sums of squares for the regression and mean sums of squares for error form an F-test statistic used to test the adequacy of the regression model. The relationship between these sums of squares is defined as follows:

$$Total\ variation = Total\ variation\ explained + Unexplained\ variation$$

The larger the explained variation, the better the model is at prediction. The larger the unexplained variation, the worse the model is at prediction. A quantitative measure of the explanatory power of a model is R^2, also known as the Coefficient of Determination (3):

$$R^2 = \frac{Explained\ variation}{Total\ Variation} \quad (3)$$

The Coefficient of Determination measures the percent variation in the response variable (y) that is explained by the model. Values range from 0 to 1. An R^2 close to zero would suggest a weak linear relation.

To complement the analysis, we have also applied Pearson's correlation coefficient given its representativeness and its use in relevant academic research on urban traffic [75,76] and telework [77]. We define the occupancy of the road as the dependant variable, with telework being the independent variable on this study.

4 Data analysis: telework and the effects on the traffic

4.1 Aggregated data analysis

Figure 1 shows the average traffic volume distribution for February 2020 in the city of Madrid, based on raw data published daily by the Madrid City Council using 7,360 vehicle detectors that count vehicles and determine the degree of urban road occupancy [74] to assess traffic distribution by the hour. Monday through Thursday were considered, as they are typical workdays in the city of Madrid and are homogeneous in terms of timetables. (Many organizations have specific schedules on Fridays; workers are often allowed to leave the office at lunchtime). Pre-COVID February 2020 was chosen to determine the baseline for traffic distribution in the city to set a threshold for the subsequent analysis, as it is important to understand former traffic patterns in order to measure the impact of a relevant increase in post-COVID19 telework.

The parameter used to observe traffic congestion is road occupancy from vehicles picked-up by traffic sensors. The road occupancy parameter indicates the percentage of time a traffic detector is occupied (by the vehicle) on average. For example, 50% occupancy in a 15-minute period means that the sensor has detected the given vehicles for 7 minutes and 30 seconds, on average [78].

Figure 2 shows the area of data collection where the sensors are distributed and captures the road occupancy that is targeted throughout this research.

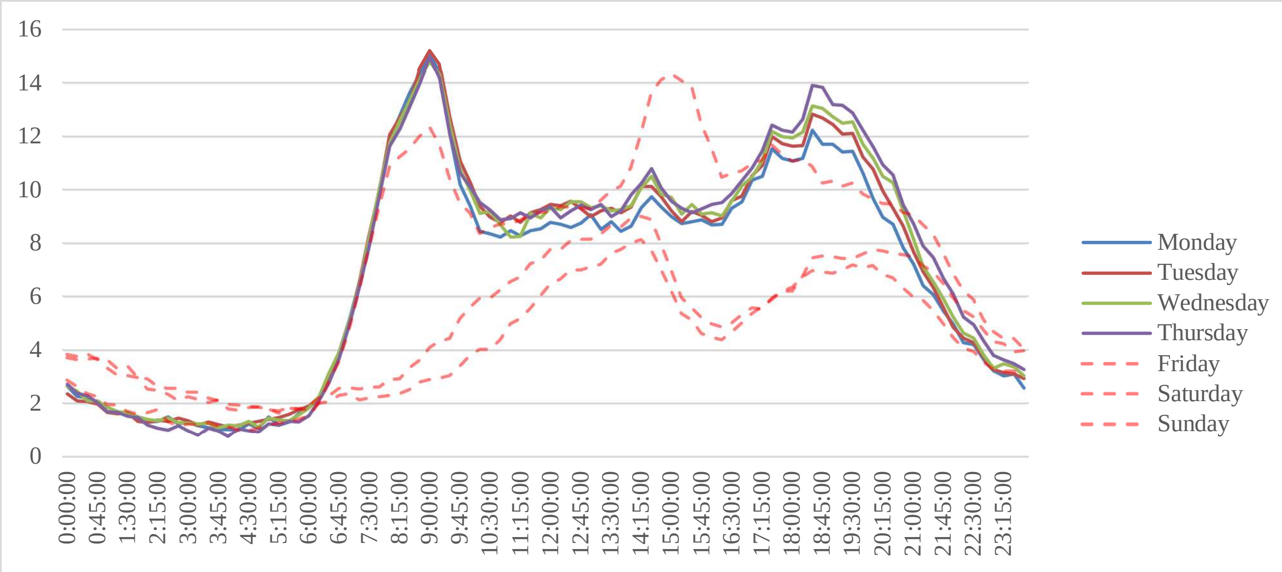

Figure 1 Daily traffic occupancy in Madrid urban areas (February 2020 aggregated mean) [73]

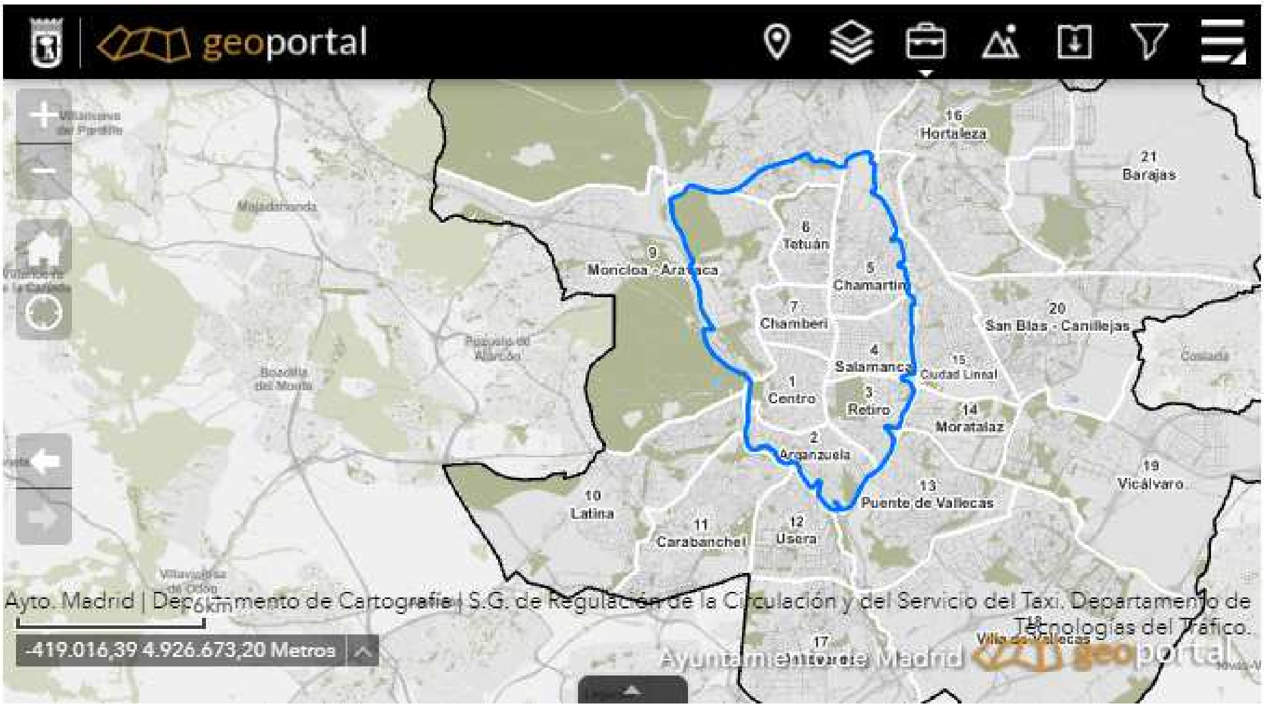

Figure 2 Area of data collection - Madrid (Spain) [79]

As illustrated in Figure 1, from Monday to Thursday, there is a concentration of traffic between 7:00 and 9:30 a.m. and between 6:00 and 8:00 p.m. These ranges correspond to the usual times for entering and leaving physical work. In other words, in a period of four and a half hours, there is a concentration of traffic due to work-related commutes in the city of Madrid.

Assuming that the 2.2 million private vehicle commutes are concentrated into these two 4.5-hour slots, and that at least 51% of the workers who can telework in Madrid [5,30] do so one day a week, Madrid would reduce traffic by 43,000 vehicles per hour. This would, therefore, improve traffic flow, substantially decrease greenhouse gas emissions, enhance air quality, and minimize the many negative effects of pollution on the environment [80].

4.2 *Impact of telework on Madrid traffic (pre-COVID vs. post-Covid)*

Table 1 shows the rate of telework implemented in Madrid from January 2019 to September 2022 and the urban traffic occupancy recorded on a monthly basis according to the following assumptions:

- Traffic occupancy measured as monthly average from the recorded data [74]
- Peak-hours considered:
  - From 7 a.m. to 10 a.m. Usual time of workplace arrival.
  - From 5 p.m. to 8 p.m. Usual time of workplace departure.
- Weekdays considered: Monday to Thursday. Friday is excluded as timetables may differ in the Spanish market where employees are allowed to leave the office at lunchtime (from 2 to 3 p.m.)
- Holidays are excluded from the analysis
- Traffic road occupancy shown as monthly based on daily averages per the above conditions.
- 2020 is excluded from the analysis due to the impact of Covid19 and the restrictions followed by public authorities could distort the target metric.

Table 1 Ocupancy and telecommuting evolution (aggregate daily peak time averages) [5,24,29,74,81]

Spot analysis		%Telecommuting	Urban traffic Load Peak
2019	Jan	8.30%	9.67
	Feb	8.30%	11.34
	Mar	8.30%	11.28
	Apr	8.30%	10.37
	May	8.30%	10.58
	Jun	8.30%	11.07
	Jul	8.30%	8.85
	Aug	8.30%	5.75
	Sep	8.30%	11.14
	Oct	8.30%	12.21
	Nov	8.30%	12.44
	Dec	8.30%	9.99
2021	Jan	27.80%	6.68
	Feb	27.80%	8.58
	Mar	27.80%	9.07
	Apr	25.80%	9.18
	May	25.80%	9.56
	Jun	25.80%	9.75
	Jul	22.10%	7.53
	Aug	22.10%	5.43
	Sep	22.10%	10.29
	Oct	21.50%	10.82
	Nov	21.50%	10.48
	Dec	21.50%	8.53
2022	Jan	23.20%	8.01
	Feb	23.20%	9.58
	Mar	22.10%	9.87
	Apr	22.10%	9.20
	May	22.10%	9.52
	Jun	22.10%	9.34
	Jul	22.10%	7.00
	Aug	22.10%	5.06

The figures shown in Table 1 contain the aggregate information from the original database to highlight the figures analyzed subsequently since each daily occupancy file contains more than 1 million rows.

Table 2 show the statistical analysis applied to understand the correlation between the rate of telework implemented and the impact on traffic during peak-times as suggested by the existing literature.

Table 2 Calculated values from statistical analysis (correlation/ANOVA)

SUMMARY OUTPUT	
Multiple R	0.335936893
R Square	0.112853596
Adjusted R Square	0.111252249
Standard Error	2.254346999
Observations	556

ANOVA

	Degrees of freedom	*Sum of Squares*	*Mean Square*	*F-Value*	*Significance F*
Regression	1	358.1553	358.1553	70.4741	3.913E-16
Residual	554	2815.4725	5.0820		
Total	555	3173.6278			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95.0%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	11.1924	0.2440	45.8626	9.09E-191	10.7131	11.6718	10.7131	11.6718
Teletwork %	-10.5952	1.2621	-8.3948	3.913E-16	-13.0743	-8.1161	-13.0743	-8.1161

Regression testing suggests a weak coefficient value of 0.3359. The closer the value is to 0, the more negative dependence there is between both variables. This result suggests that telework does not have a strong impact on traffic in Madrid. In line with this result, according to the R Square that shows the value of the coefficient of determination, the result obtained from the regression is 0.11 which represents an only 11% meaning that the strength of the linear relation between both variables is weak.

The standard deviation shows a low value indicating that the behavior of both variables is stable and consistent within this system.

The ANOVA test has also been considered taken into account to allow for the testing of the null hypothesis which considers that the model chosen to explain the dependency between telework and peak traffic is not adequate. An F test is obtained to check this assumption. F-significance is close to 0 ($3.91x10^{-16}$) being lower than 0.05 (α-significance level). This means that null hypothesis can be rejected so that this model is correct in explaining the weak relationship between both variables.

Another index used to confirm the hypothesis that telework does not contribute significantly to traffic improvement during peak times is the Pearson correlation coefficient (4) between telework and peak traffic.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (4)$$

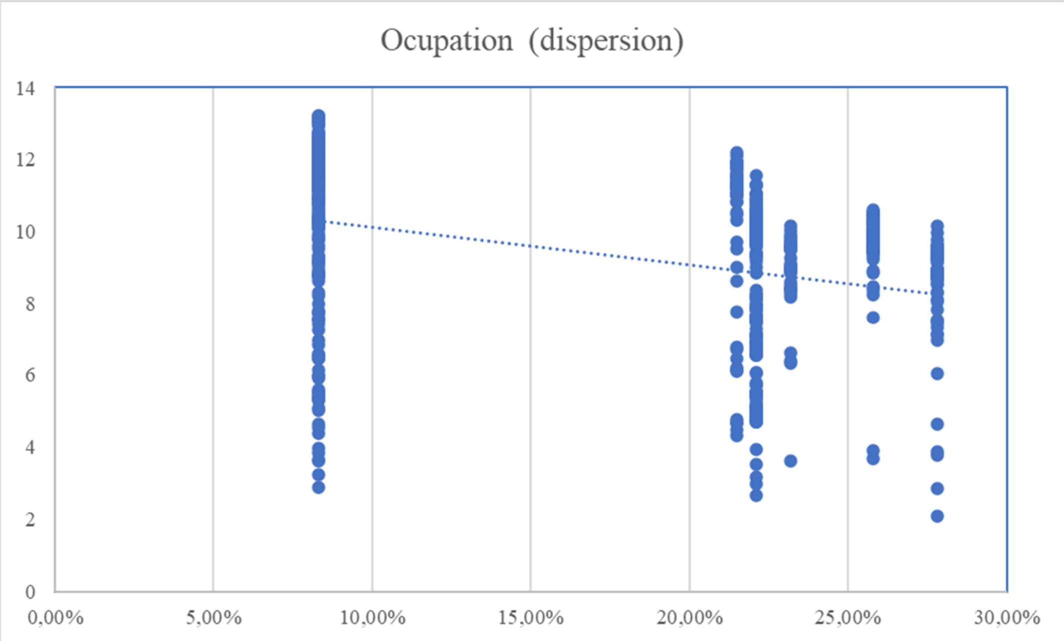

Figure 4 Pearson correlation coefficient – telecommuting/traffic occupancy (p=0.05)

Figure 4 shows the dispersion of the correlation between telecommuting and traffic occupancy where the correlation coefficient (r) is -0.33593. The negative coefficient shows an inverse relationship between the two variables in such a way that when telework increases, traffic in Madrid decreases, but this correlation is limited given the value obtained as per Table 3.

Table 3 Pearson coefficient value interpretation

r = 1	Perfect correlation
0.50 < r < 1	High degree
0.30 < r < 0.49	**Moderate degree**
0 < r < 0.29	Low degree
r = 0	No correlation

These results confirm that the effect of telework on reducing traffic in Madrid is not so sensitive, suggesting that the decrease in traffic due to telework does not occur in the same proportion, or at least in any significant proportion. This circumstance may thus indicate a presumed change in the pattern of consumer behaviour with regard to the modal choice on days when they must travel to work in person.

5 Conclusions

The result of our analysis leads us to conclude that, although telework reduces the number of trips in urban environments, the positive impact on traffic in the city of Madrid during peak times is limited, regardless of what is generally expected when eliminating commutes. The decrease in traffic in Madrid is not proportional to the increase in telework that is taking place. Three reasons may be behind this limited positive effect. First, COVID-19 still causes some misgivings about using public transport for health and hygiene reasons. Second, in the city of Madrid, out of the 22.1% of employees who work from home, 9.6% telework occasionally, that is less than 50% of the work week, meaning they commute to the workplace the remainder of the week. On these commutes a change in consumer behaviour may be occurring, such that consumers tend to opt for private cars. This change in consumer behaviour may be attributable to convenience, economic savings (on the transport fare), or an employee's willingness to incur higher transport costs by using a private car if commutes are limited to only a few days a week. Third, telework allows workers to make decisions about their place of residence in such a way that they can decouple this decision from the workplace, allowing them the possibility of residing in locations where the cost of living is lower. This influences people's mobility and transport as these locations are further away and have a more limited supply of public transport. This, in turn, causes an increase in the distances travelled and may favour the use of private vehicles.

The findings give rise to a set of implications for transport providers, given that telework influences mobility patterns and mode of transport choice. These implications suggest transport providers could implement a few lines of actions to adjust the transport infrastructure to the new context in urban areas, where the implementation of telework is widespread. Urban mobility constitutes a strategic element in terms of sustainability, given its impact on the carbon footprint. Therefore, any change in urban mobility patterns, as the results of this research suggest, must be considered to encourage public transport use, owing to its contribution to sustainable mobility [82]. Thus, it may involve the adaptation of both infrastructure and planning given the noted impact of telework on traffic.

At the same time, researchers suggest the need for further examination of the factors influencing mode of transport choice for people who work full- or part-time from home. Also, reducing traffic during peak times is a question that is more achievable through time flexibility at work to avoid commutes during peak times. The analysis carried out, though it attempts to refine the data obtained from the analysis of road use in the city of Madrid, still includes some journeys that are not for work purposes. Thus, this research highlights the need for further research, for the city of Madrid or others to provide a better understanding of the factors that influence the modal choice of consumers, through either quantitative or qualitative means given the evidence of the limited impact of telework on traffic.

Declaration of conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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The manuscript is based on the public information made available by the entities that have been cited herein. Database repositories are named in the reference lists.

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Review process

Single-blind peer review process.