Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2022) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

A critical assessment of Athens Traffic Restrictions using multiple data sources

Antonis Chaziris[a]*, George Yannis[b]

[a]*Research Associate, Iroon Politechniou 5, Athens, 15773, Greece*
[b]*Professor, Iroon Politechniou 5, Athens, 15773, Greece*

Abstract

This paper presents for the first time, a critical assessment of Athens Traffic Restrictions (ATR) by analyzing data on traffic volumes and speeds from the Traffic Management Centre of Athens, as well as ticket validations from Athens public transport operator (OASA S.A.). ATR were reinstated on 24 October 2021 as a response to increasing congestion, due to heightened social activity in the aftermath of the COVID pandemic. The analysis showed an increase in average speeds and reduction in congestion inside ATR throughout the study period. Outside ATR, no conclusive evidence was found supporting a persistent impact of the measure on traffic. The reinstatement of ATR contributed to the increase in metro ridership. Transport and local authorities should set clear goals and appropriate KPIs to monitor the success of the measure in the long term. The potential of mode switch from cars to public transport is promising and should be taken into account in this goal setting. Enhancing the implementation of ATR with micromobility options and MaaS solutions inside the restricted area can further boost compliance and strengthen the uptake of public transport.

Keywords: Urban traffic; Traffic measures; Mobility data; Sustainable cities and communities; Traffic efficiency

1. Introduction

Urban transportation policies throughout Europe have evolved dramatically during the last decades. The significant economic development and urbanisation led to a significant increase in the number of passenger cars and the vehicle-kilometres driven (Marrero et. al, 2019) as well as GHG emissions from transport (EEA, 2019). Transport policies, which initially aimed at increasing the capacity of the road transportation system, shifted towards the optimization of

* Corresponding author. Tel.: +30-210-772-4715;
E-mail address: achaz@mail.ntua.gr

traffic operations and eventually to the disincentivization of car use in favor of public transport and active travel modes, leading to a new paradigm for urban development, spearheaded by the recently developed EU Urban Mobility Framework (EC, 2021). The digital revolution further accelerated this transition by enabling analyses and data exploitation methods that were not available in the past. In the light of these developments, it is important to reassess ageing transportation policies and their related measures, in order to enable meaningful contributions to national and EU policy goals.

Athens is a city with a population of 660.000 people (3 million in the greater Athens area). The city spans over an area of 39 km^2, with a total road network of 868 kilometres. In 2020 the total number of vehicles in the city of Athens was 4,4 million, 69% of which were private vehicles. Traffic in Athens has been steadily increasing from the onset of motorization in the 1960's till 2008 and the global economic crisis. A significant reduction of private car use during the first years of the recession and a rebound in traffic from 2017 followed, leading to 2019 when traffic closely resembled pre-2009 levels. The coronavirus pandemic and the respective lockdowns resulted in additional fluctuations in car traffic, which were accompanied by a significant reduction of public transport use. In October 2021, a significant increase in traffic congestion was observed in Athens, leading the authorities to reinstate previous traffic restrictions in Athens, which have been suspended from March 2020 due to the pandemic.

The restrictions, which limit the use of private cars within the centre of Athens, were first implemented in 1979 and were made permanent in 1982. More specifically, private car access to a designated area in the city centre is controlled according to the last number of the car's license plate. On even dates, cars with an even license plate last number are permitted within the area while cars with an odd number are not, and vice-versa. In 2017, an attempt to improve environmental conditions within the city centre, the authorities modified the conditions to enter the designated area, lifting restrictions for electric vehicles as well as vehicles emitting low amounts of CO2.

Similar traffic restrictions are implemented in other European cities, mostly focusing on road pricing to reduce congestion. Prominent examples include the London Congestion Charge (TfL, 2021) and the Congestion tax in Stockholm (Transport Styrelsen, 2021) as well as the creation of low emission zones, such as the Area C scheme in Milan (Kodukula et. al, 2013), the low emission zones in Paris (Bernard et. al 2020) and Amsterdam (City of Amsterdam, 2019) or the Ultra Low Emission Zone in London (Greater London Authority, 2020).

A significant debate among policy makers, experts and citizens is ongoing whether the Athenian restriction scheme can live up to the needs of a 21st century metropolis, especially in the light of the pandemic and the overall reduced use of public transport. The multitude of available traffic data provides opportunities not present a few years ago, to analyze the efficiency of traffic measures and understand their contribution towards a green and efficient transport system.

2. Methodology

The present paper initially presents an analysis of traffic volume and speed data from 79 measurement stations (each consisting of one to three inductive loop detectors) from the Traffic Management Centre of Athens. 46 of the selected measurement stations are located outside and 33 inside Athens Traffic Restrictions area. The traffic data are publicly available through the national portal data.gov.gr and cover the period from November 2020 till the present day. The data are available on an hourly basis, however, this study uses weekly aggregates as the focus is on the long term variation of the traffic measures rather than the daily or weekly variation. The study is focusing on the period from October till December 2021, as Athens Traffic Restrictions were reinstated at 24 October 2021, while the imposed restrictions (traffic, social, etc) due to the COVID pandemic during the same period did not change significantly.

In order to further examine the effect of ATR on road traffic conditions, an indicator reflecting the level of congestion in the vicinity of each measurement station was developed (Congestion Index). The Congestion Index can be aggregated over several measurement stations to shed light on the congestion level of an entire area. In order to obtain such a measure the dimensions of traffic volume and speed for each measurement station were combined to produce a robust indicator based on its unique fundamental diagram of traffic flow. By exploiting the unique fundamental diagram of each measurement station, traffic operations for each speed – volume pair can be classified either nominally (free flow, congestion, etc), or numerically (by assigning a congestion index).

The classification method developed in this research is twofold: on the one hand as speed decreases, congestion increases and on the other hand, for volume – speed pairs reflecting neither free flow, nor congestion (in the vicinity of the “curve” of the fundamental diagram), lower congestion indexes are assigned for higher traffic volumes (up to a maximum level). The classification thresholds are unique to each measurement station and are based on the characteristics of its speed and volume distributions. The above classification assigns an index ranging from 0 (free flow – green color) to 1,5 (extreme congestion – red color) to each speed – volume pair, which can subsequently be plotted on top of the fundamental diagram, as seen in Figure 1.

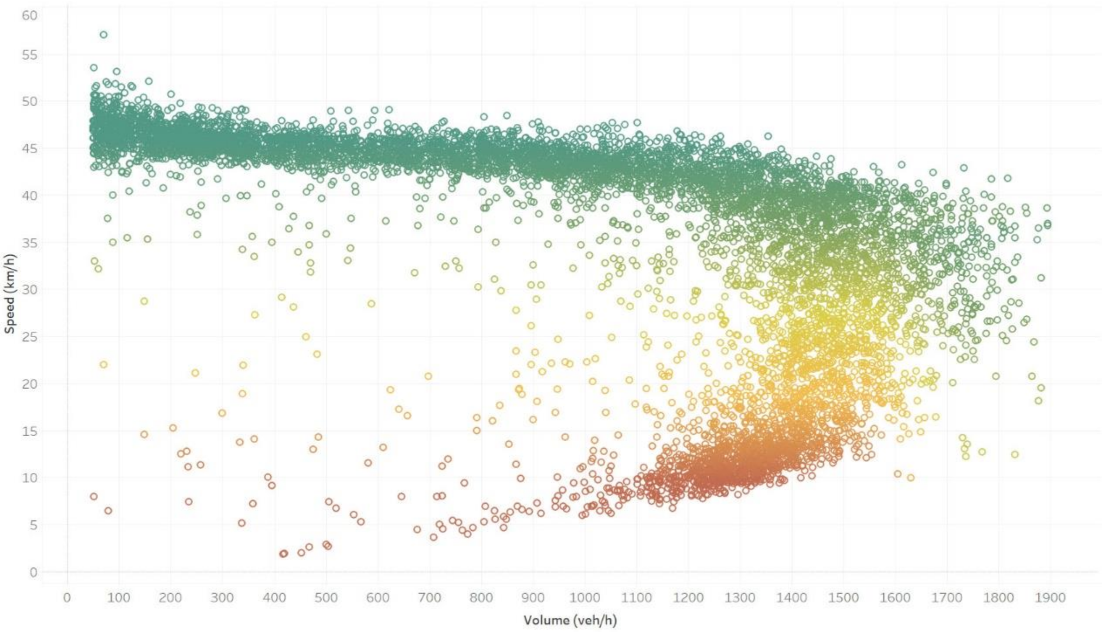

Fig. 1. Classification of speed – volume pairs based on the developed Congestion Index.

The congestion index can be averaged over several measurement positions and time periods in order to produce comparable numerical aggregate estimates of the congestion in an entire area. In this study, weekly aggregates for the measurement stations inside and outside ATR are generated in order to further examine the effect of the reinstatement of the measure to traffic conditions.

Finally, in order to understand whether the effects of the reinstatement of ATR on road traffic were associated with a respective effect on the use of public transport, data on the use of the Athens Metro system inside ATR were exploited. More specifically, ticket validations from Athens public transport operator OASA S.A. (also available through the data.gov.gr portal) were analyzed for 13 metro stations within the Athens Traffic Restrictions area.

3. Results

This paper presents for the first time, a critical assessment of Athens Traffic Restrictions (ATR) by analyzing data on traffic volumes and speeds from the Traffic Management Centre of Athens, as well as ticket validations from Athens public transport operator OASA S.A. The following sections examine the impact of the reinstatement of the measure on various metrics, inside and outside the restrictions area.

3.1. Traffic demand

Figure 2 shows the evolution of the total daily traffic demand (7-day moving average) inside and outside ATR, from October till December 2021. The data refer to 46 measurement stations outside ATR and 33 measurement stations inside ATR. An initial visual inspection of the graph suggests that traffic demand evolves similarly inside and outside ATR for the entirety of the examined period.

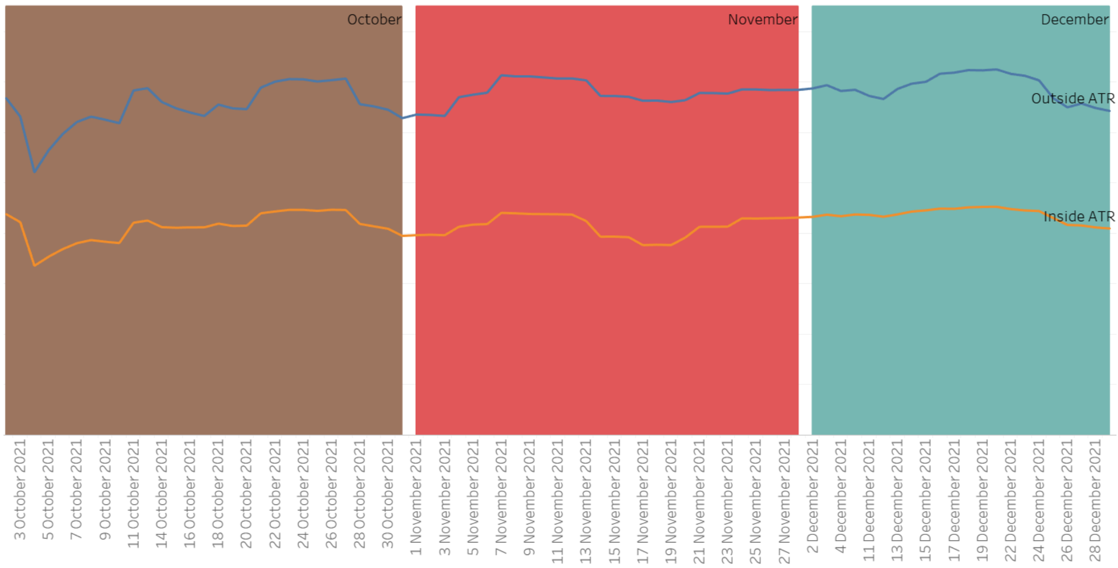

Fig. 2. Evolution of road traffic demand in Athens (vehicles / day – 7 day moving average).

The evolution of the total traffic demand inside and outside ATR does not seem to suggest a fundamental redistribution of traffic due to the reinstatement of the measure on 24 October 2021, however, in order to obtain a detailed picture about the effect of the measure on traffic conditions, a more rigorous approach is required. On that purpose, the following sections examine the effect of the reinstatement of on traffic speeds, congestion and public transport use.

3.2. Traffic speeds

Athens Traffic Restrictions were reinstated in the beginning of week 44 of 2021. In order to examine the effect of the measure on traffic operations, the average weekly speed is calculated both inside and outside the restrictions. The data refer to the same measurement stations used for the calculation of traffic demand.

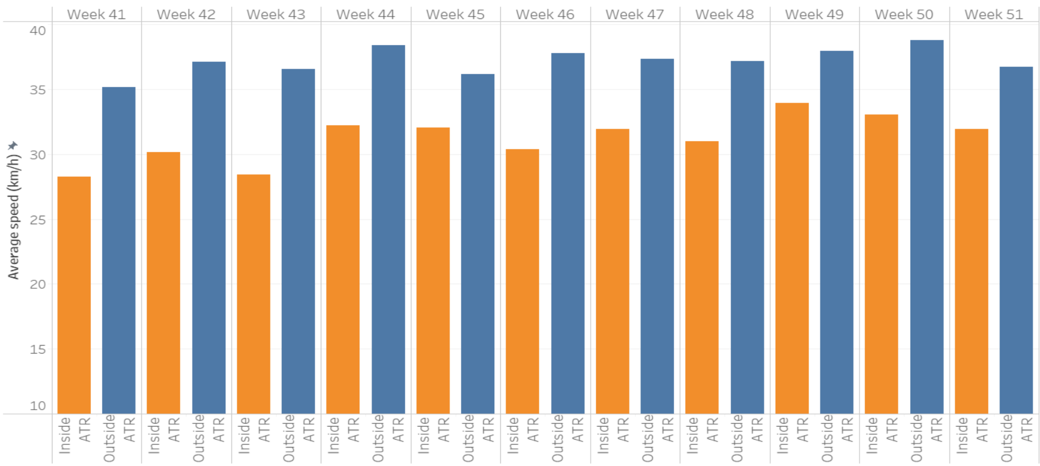

Figure 3. Average speed (morning peak) inside / outside ATR, per week.

Figure 3 presents the average weekly speed for the morning peak (08:00-10:00 a.m). An increase in weekly average speeds inside ATR can be observed starting from week 44, compared to the first three weeks of October (41-43). This increase seems to be sustained throughout the study period. On the other hand, outside ATR the difference on traffic speeds between the baseline (weeks 41-43) and the rest of the time period seems to be smaller.
To assess the significance of the observed differences, the speeds of weeks 41, 42 and 43 are averaged and used as reference. Table 1 presents the difference in average speeds between the baseline (weeks 41-43) and each week after that for the morning peak. Moreover, the statistical significance of these differences are provided in the form of p-values (inside parentheses), under the null hypothesis that no change in average speeds is present. The results presented on Table 1 show that a significant increase in average speed can be observed inside ATR compared to the period before the reinstatement of the measures, throughout the study period (except for week 46), at a 1% level of significance. Outside ATR the results are less conclusive, as the smaller differences in the average speed are only significant for three out of the eight weeks of the period after (at a 1% level of significance).

Table 1. Average speed difference (morning peak – km/h) before and after the reinstatement of ATR.

		Week 44	Week 45	Week 46	Week 47	Week 48	Week 49	Week 50	Week 51
Inside ATR	Before (weeks 41, 42, 43)	3,29 (1,2e-03)	3,14 (2e-04)	1,47 (0,0152)	3,01 (0)	2,1 (1,6e-03)	4,98 (0)	4,65 (0)	3,01 (0)
Outside ATR	Before (weeks 41, 42, 43)	2,48 (0)	0,1 (0,58)	1,52 (1,1e-03)	0,99 (0,034)	0,87 (0,121)	1,65 (0,033)	2,39 (2e-03)	0,44 (0,28)

H0: speed before and after did not change, H1: speed after the reinstatement was increased

It should be noted that for the off-peak periods (00:00-07:00 a.m. and 21:00-23:59 p.m.) the speed differences before and after the reinstatement of the measure, both inside and outside ATR are significantly lower and were not found to be statistically significant across the study period.

3.3. Congestion

The increase in average traffic speed inside ATR during the morning peak reveals a significant effect of the reinstatement of the measure on traffic operations. However, an increase in the weekly average traffic speed is difficult to be translated into a tangible difference on driver experience. In order to further investigate this aspect, an examination of the change in congestion levels is attempted, based on the concept of the Congestion Index described in the methodology.
Figure 4 presents the weekly evolution of the average Congestion Index inside and outside ATR, before and after the reinstatement of the measure. A visual inspection of the graphs reveals concordance with the results for average traffic speeds. More specifically, inside ATR, compared to the baseline (weeks 41-43), a notable reduction in congestion can be observed in the first two weeks after the implementation (44, 45), followed by a slight increase (weeks 46-48) and a subsequent decrease in December (weeks 49-51). Outside ATR, the results are also concordant with the speed observations, with the congestion index being notably lower on weeks 44 and 46 compared to weeks 41-43, whereas week 45 has been more congested. However, it is important to examine whether the differences in the congestion indexes are statistically significant, but also to co-examine the statistically significant differences in CI and traffic speeds.

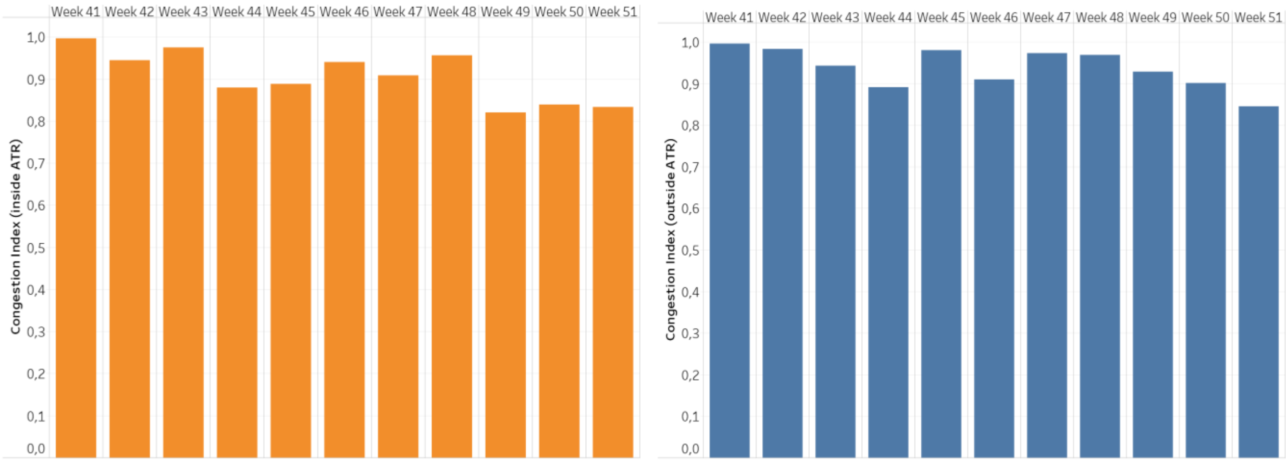

Figure 4. Congestion Index (morning peak) inside / outside ATR, per week

Table 2 presents the difference in the average Congestion Index between the baseline (weeks 41- 43) and the subsequent weeks of the study period both inside and outside ATR. Inside ATR Congestion Indexes are decreased throughout the period after the reinstatement, however the reduction is statistically significant at a 1% level only for weeks 49, 50 and 51. Outside ATR, statistically significant reductions in the Congestion Index are observed for week 44, 46, 50 and 51.

Table 2. Congestion Index difference (morning peak) before and after the reinstatement of ATR.

		Week 44	Week 45	Week 46	Week 47	Week 48	Week 49	Week 50	Week 51
Inside ATR	Before (weeks 41, 42, 43)	-0,092 (0,017)	-0,089 (0,011)	-0,018 (0,247)	-0,056 (0,046)	-0,009 (0,395)	-0,152 (1,2e-04)	-0,156 (3e-05)	-0,130 (2e-05)
Outside ATR	Before (weeks 41, 42, 43)	-0,076 (9,5e-04)	0,007 (0,68)	-0,067 (4,7e-04)	-0,009 (0,34)	7e-04 (0,51)	-0,05 (0,061)	-0,103 (8e-04)	-0,113 (0)

H0: CI before and after did not change, H1: speed after the reinstatement was reduced

As can be observed from Tables 1 and 2, a significant increase in average traffic speeds during the peak hours inside ATR, does not always correspond to a significant decrease in the Congestion Index. For example, the significant increase in traffic speeds for weeks 44, 45, 47 and 48 does not correspond to a significant decrease in the Congestion Index at a 1% level of significance. This can be explained by the composite nature of the Congestion Index which takes into account traffic volumes apart from speeds. Depending on the geometric and traffic characteristics of a road section, an increase in average speed might not always be accompanied by a significant increase in traffic volumes, resulting in a non-significant change in the Congestion Index. On other occasions (weeks 49, 50, 51), the increase in traffic speeds during the peak hours inside ATR, corresponds to a significant decrease of the Congestion Index, providing more concrete evidence for the improvement of traffic conditions in that area and time period.

Outside ATR, the results for traffic speeds and the Congestion Index are in agreement, as a significant decrease in the Congestion Index can be observed for every week with a significant increase in average speed. In this case, the Congestion Index can offer complementary evidence on occasions where the results about the speed differences are somewhat inconclusive. For example, inside ATR during the morning peak, the speed difference between week 47 and the baseline (weeks 41-43) is not significant at a 1% level of significance, while it is at a 5% level. In that case, by examining the corresponding CI difference, it can be inferred that the congestion levels did not change significantly.

3.4. Public transport use

The results presented in the previous sections shed light onto the changes in road traffic inside and outside ATR. However, it is interesting to examine how and if the observed differences were accompanied by respective changes in the use of public transport. On that purpose, the use of the Athens Metro system inside ATR is examined by exploiting data on ticket validations from Athens public transport operator OASA S.A. The data refer to 13 metro stations within the Athens Traffic Restrictions area.
Unfortunately, data on ticket validations were not available for weeks 42 and 43, therefore only week 41 is considered as the baseline. As in the previous cases, the baseline is compared to the weeks after the reinstatement of the measure 44-51 both qualitatively and quantitatively.

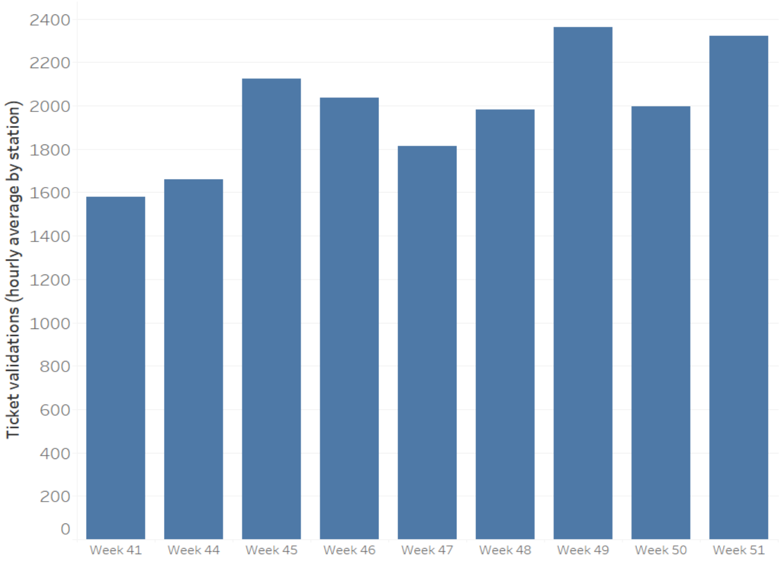

Figure 5. Metro ticket validations (morning peak, hourly average per station) inside ATR, per week

A notable increase in public transport use inside ATR can be observed after the reinstatement of the measure, for the entirety of the study period, which is more evident from week 45 onwards. The statistical significance of the differences is presented on Table 3.

Table 3. Average difference (in hourly validations per metro station) before and after the reinstatement of ATR.

		Week 44	Week 45	Week 46	Week 47	Week 48	Week 49	Week 50	Week 51
Inside ATR	Before (weeks 41, 42, 43)	80 (1,8e-03)	545 (0)	455 (0)	233 (0,01)	403 (1,7e-04)	780 (0)	417 (1,4e-04)	743 (0)

H0: validations before and after did not change, H1: validations after the reinstatement were increased

As can be seen from Table 3, ticket validations in metro stations inside ATR were significantly increased (at a 1% level of significance) compared to the period before the reinstatement of the measure. The results suggest that the reinstatement of ATR contributed to an increase in public transport use, with road users switching from using their private cars to using the metro in order to move inside the ATR area.

4. Conclusions

This paper presents for the first time, a critical assessment of Athens Traffic Restrictions (ATR) by analysing data from multiple sources, before and after the reinstatement of the measure with the ultimate purpose of understanding the effects on the amount of traffic and public transport use inside and outside the restriction area. Furthermore, the results provide useful insights that will enable the evolution of the traffic measure into a contemporary tool in accordance with the national climate and transportation goals.

An increase in weekly average speeds inside ATR, sustained throughout the study period, was observed after the reinstatement of the measure. The Congestion Index inside ATR also decreased throughout the period after the reinstatement, however the reduction was found to be statistically significant only for three out of the eight weeks. This reveals a concrete impact of the measure on improving road traffic conditions inside the restrictions area. Outside the restrictions area, no conclusive evidence was found supporting a persistent positive impact of ATR on traffic conditions. However, it can be concluded that the reinstatement of ATR did not have an adverse effect on traffic conditions outside ATR throughout the study period.

Reduced congestion, resulting to higher vehicle speeds within the examined network can potentially lead to reduced road safety, especially for vulnerable road users. Moreover, less congestion can potentially lead to an overall reduction in emissions from traffic, contributing to the city's transport sustainability goals. Further research addressing those issues can shed additional light to the effects of ATR in citywide mobility. The reinstatement of the restrictions contributed to the increase in metro ridership inside ATR .This is an important conclusion taking into account the fact that the pandemic acted as a deterrent for public transport use throughout the study period. Overall, the reinstatement of Athens Traffic Restrictions had a positive impact on road traffic speeds and public transport ridership. The impact on congestion however, although present, was not as persistent throughout the study period.

The impact of the reinstatement of ATR on transport equity was not examined in this study and is an interesting venue for further research. Traffic restrictions lead to increased public transport use, reducing its level of service, if supply is not increased. This means that the reinstatement of ATR potentially benefits those well enough off to own or use cars, whereas reduced LOS on public transport disadvantages those who may not have other travel options available to them. The non-restricted entry of electric vehicles inside ATR can boost the uptake of less polluting means of transportation, however, this might have an adverse effect on congestion, since EV's contribute to the phenomenon as much as regular vehicles. Considering the above, transport authorities, the municipality of Athens and the Region of Attica should set clear goals in deliberation with citizens and define appropriate KPIs in order to monitor the success of the measure in the long term. Strict enforcement in the long term is crucial for sustaining any short and mid-term effects from the implementation of ATR. Past experience with the implementation of the measure suggests that enforcement actions tend to be relaxed over time, with a respective negative effect on compliance.

The evolution of the measure into a contemporary tool in accordance to the EU urban mobility and climate frameworks will ultimately depend on the goals set by the national and local public authorities. However the potential of mode switch (from cars to public transport) from the implementation of ATR as demonstrated in this study, is promising and should be taken into account in this goal setting.

References

EEA Report No 16 / 2019. Annual European Union approximated greenhouse gas inventory for the year 2018.

Marrero, Gustavo & López, Jesús & González, Rosa Marina, 2019. Car usage, CO2 emissions and fuel taxes in Europe. Journal of the Spanish Economic Association. 10.1007/s13209-019-00210-3.

European Commission, The new EU Urban Mobility Framework, Strasbourg, 14.12.2021

Transport for London, 2021.Greater London (Central Zone) Congestion Charging Order 2004.

Greater London Authority, 2020. Central London Ultra Low Emission Zone – Ten month report.

Transport Styrelsen 2021, Congestion tax in Stockholm, www.transportstyrelsen.se

Kodukula, Sunny & Morandini, Marco. (2013). The Ecopass pollution charge and Area C congestion charge - comparing experiences with cordon pricing over time.

Bernard Y., Miller J., Wappelhorst S., Braun C., 2020. Impacts of the Paris low-emission zone and implications for other cities. The Real Urban Initiatives Report.

City of Amsterdam, 2019. Emission Free Amsterdam - Clean Air Action Plan.

Find Open Data, accessed April 2021, https://data.gov.gr/