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Exploring traffic evaporation: Findings from tactical urbanism interventions in Barcelona

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A R T I C L E I N F O

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A B S T R A C T

Traffic evaporation – i.e. the opposite of induced traffic – is acknowledged as a well-established phenomenon which presents important implications for local urbanism and mobility policies, but there continue to be few academic studies which explore this issue in detail. This paper explores relative levels of traffic evaporation following the implementation of multiple tactical urbanism interventions on 11 streets in Barcelona in the context of the COVID-19 pandemic. Based on the analysis of publicly available traffic count data, the findings provide empirical support for the existence of significant levels of traffic evaporation following road space reduction. On average, traffic levels on streets with interventions diminished by −14.8 % relative to streets in the rest of the city. In the wider vicinity of intervention streets, traffic levels also decreased slightly on average (−0.9 %) compared to the rest of the city, except on immediately adjacent parallel streets to those affected by interventions, which reported a small relative traffic increase (+0.7 %). Overall, these findings provide further support for street redesign policies which entail the reduction of road space for motor vehicles, and suggest that fears of traffic congestion following such schemes may often be unfounded. From a methodological standpoint, this study also offers a transparent method of evaluating traffic evaporation which could be replicated in future studies.

1. Introduction

In recent years, measures seeking to reallocate road space from motorised traffic to active travel modes and other public space uses have gained widespread popularity worldwide. This “reclaiming” of car space for other uses is increasingly seen as critical in encouraging an urban mobility transition towards low-carbon transportation and more liveable cities (Petzer et al., 2021; Tennøy and Hagen, 2021). In particular, “tactical urbanism” – i.e. the speedy implementation of low-cost infrastructural interventions in the public realm, often with a temporary or experimental character – has become a prominent strategy for city administrations to push forward measures which entail a reduction in the amount of space allocated to motorised traffic (Lydon et al., 2015; Sadik-Khan and Solomonow, 2016). In this respect, tactical interventions can be understood as a form of street experiment which seek to recast streets as spaces “for people” rather than “for traffic” (Bertolini, 2020). The concept of tactical urbanism has its origins in small-scale unsanctioned bottom-up interventions carried out by ordinary residents and neighbourhood groups (Finn, 2014; Silva, 2016). In recent years, however, tactical interventions have increasingly been promoted by public authorities themselves as a strategy to implement rapid changes in the public realm. Especially in the context of the COVID-19 pandemic, tactical urbanism has become a common means of reallocating road space from motorised traffic to active travel, public transport, and public space use (Glaser and Krizek, 2021; Rojas-Rueda and Morales-Zamora, 2021).

Nevertheless, and as the title of Janette Sadik-Khan’s account of her time as transport commissioner in New York suggests – *Streetfight* (Sadik-Khan and Solomonow, 2016) – tactical street interventions often lead to a vocal confrontation between their proponents and opponents, which relies on partisan argumentation with little empirical support, and is highly subject to media narratives. Indeed, street interventions which reduce the amount of space dedicated to motorised traffic typically face entrenched resistance from a wide variety of actors, including business and motor vehicle lobbies, residents, taxi drivers, and municipal traffic engineers among others (Hickman and Huaylla Sallo, 2022). While such schemes are resisted on the assumption that they will increase traffic congestion, in reality it appears that they frequently lead to a reduction

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in overall traffic levels, a phenomenon which has been named "disappearing traffic" or "traffic evaporation" (Cairns et al., 2002; Nello-Deakin, 2020). Up to date, however, relatively few empirical studies have sought to explore the issue of traffic evaporation in detail. As argued by Nello-Deakin (2020), further empirical research on traffic evaporation can play a critical role in helping policymakers justify road space reallocation schemes in the eyes of the public (or justify the concerns of their critics). In this sense, documenting and quantifying traffic evaporation is critical in order to evaluate the effects of road space reallocation schemes, and can indirectly contribute to advancing urban liveability by providing a solid evidence base for traffic reduction measures.

Following this rationale, the present paper seeks to assess relative levels of traffic evaporation following multiple tactical urbanism interventions implemented in Barcelona in the context of the COVID-19 pandemic, using traffic count data collected by the local municipality. More generally, the paper also offers a methodological contribution to the existing literature on traffic evaporation by proposing a transparent way of assessing *relative* changes in traffic levels on intervention streets (and their vicinity) compared to the rest of the city, which could be fruitfully replicated in future empirical studies.

The paper begins with a literature review section which examines the existing academic literature on traffic evaporation, linking it to wider issues of street space distribution. After this, I present the methodology used to assess changes in traffic levels (and relative levels of traffic evaporation) following street redesign. The next section focuses on the case study and its empirical results, first describing the tactical interventions implemented in Barcelona, and situating them in the context of the tactical urbanism interventions which numerous cities worldwide carried out during the COVID-19 pandemic. The discussion section considers the implications of the findings, while the final conclusion summarises them and highlights some avenues for future research.

2. Literature review: The phenomenon of traffic evaporation

Briefly defined, traffic evaporation or "disappearing traffic" (Cairns et al., 2002) refers to the reduction in traffic flows which is often observed following a reduction in road space capacity. The existence of this phenomenon means that the impacts of road space reduction on traffic congestion are less severe than predicted by traffic models which assume traffic levels to be inelastic. Traffic evaporation can be thought of as the opposite of induced traffic, i.e. the observed rise in traffic volumes following road capacity expansion. Although induced traffic has been more thoroughly studied than traffic evaporation (Bucsky and Juhász, 2022; Goodwin, 1996; Litman and Colman, 2001), the latter currently seems a more pressing topic of study given the urgent need to transition to transportation systems which rely less on private car use. Regarding the mechanisms which may explain traffic evaporation, one may consider three broad possible explanations, including 1) trip rerouting beyond the area of measurement; 2) modal shift; and 3) trip suppression (Cairns et al., 2002; Melia and Calvert, 2021). In the third case, these "suppressed trips" are associated with wider changes in individual travel practices such as a change of destination, working from home, or car-sharing. Over the long term, reduced road space capacity might even lead to changes in residential and activity location.

More generally, the issue of traffic evaporation also connects with wider debates on the distribution of street space and its relationship to issues of urban equity and fairness, which are becoming an area of increasing academic attention (e.g. Creutzig et al., 2020; Gössling, 2016; Guzman et al., 2021; Nello-Deakin, 2019). As these accounts stress, motorised traffic is currently granted a disproportionate share of the scarce public space in modern cities, which could be more equitably and efficiently used if it were dedicated to other functions. Since car use remains restricted to specific population groups in most cities, this prioritisation of the interests of car drivers over the needs and desires of other citizens may reproduce and amplify existing urban and transport inequalities (Hartman and Prytherch, 2015; Illich, 1974).

Despite being written two decades ago, a summary article by Cairns et al. (2002) continues to provide the best available overview of the existing state of knowledge on traffic evaporation. Indeed, it is difficult to disagree with Melia and Calvert's (2021) recent appraisal of the existing literature on the topic: "two observations stand out: the breadth of the two original studies (Cairns et al., 1998, Cairns et al., 2002) and the limited advance of knowledge on the subject since then" (p.2). Building on a previous study which reviewed more than 70 road space reallocation schemes (Goodwin et al., 1998), Cairns et al. found that 51 of the 70 schemes reported a decrease in traffic levels, compared to only 11 schemes which reported an increase in traffic. The median observed reduction in traffic was 11 % across all schemes, but the authors noted that there was wide variability between cases, partly because of the different geographical scales and time periods under study. Furthermore, they noted that it is difficult to disentangle the effects of road schemes from natural variability in traffic levels.

Beyond these two original studies, there exist a handful of more recent academic articles on traffic evaporation following temporary or permanent road closures. Some of these focus on *planned* road closures (e.g. Chung et al., 2012; Hunt et al., 2002; Tennøy and Hagen, 2021), while others examine the effects of *unplanned* disruptions (Zhu et al., 2010). Another notable feature of various of these studies is their focus on bridges (Bucsky and Juhász, 2022; Hunt et al., 2002; Zhu et al., 2010) or tunnels (Tennøy and Hagen, 2021), which provide good case studies since they allow to clearly isolate the impact of their closure (or capacity reduction) on the wider road network. By and large, these studies have reported comparable conclusions: namely, that traffic levels tend to adapt to reductions in road space capacity, and that road congestion impacts tend to be less severe than predicted by conventional traffic models. Nevertheless, the widely different focus of each study (geographical context, timeline, type of intervention) means that establishing comparisons between cases remains difficult. This said, reported reductions in traffic levels following partial road capacity reduction tend to be on the order of −5% to −25 %, (e.g −4.4 % in Hunt et al. (2002); −23 % in Tennøy and Hagen (2021)), which is consistent with the findings of the review article by Cairns et al. (2002). These rates are also similar to those reported by the Municipality of Paris (−5 to −28 %) along alternative traffic routes following the pedestrianisation of the right bank of the river Seine (Varoquier and Hasse, 2018).

Although most studies limit themselves to trying to quantify the extent of traffic evaporation following the reduction of road space, some also seek to explore the underlying mechanisms and behavioural responses which may explain this reduction in traffic flows, such as modal shift or trip suppression. In these cases, analysis of traffic count data is supplemented by a survey of travel behaviour changes in vicinity of scheme area (Hunt et al., 2002; Melia and Calvert, 2021; Zhu et al., 2010), occasionally complemented by an exploration of changes in public transport ridership (e.g. Chung et al., 2012). The emerging consensus from these studies is that the degree of behavioural change and modal shift away from motorised travel tends to be proportional to the level of disruption to the existing car traffic network.

While these studies have contributed to generate growing evidence of traffic evaporation, the fact remains that "significant knowledge gaps remain as a priority for future research" (Melia and Calvert, 2021, p. 1). At the most basic, there is a need to further build up a critical mass of empirical evidence documenting traffic evaporation across a variety of geographic settings. Likewise, there still exists relatively little research exploring the effects of road space reallocation schemes beyond the local intervention area, or the cumulative effect of multiple neighbouring interventions. Although road space reallocation schemes have become more popular than ever in the light of the COVID-19 pandemic, the fact remains that "politics, financial pressures on local authorities and practical challenges often curtail the scope of traffic removal schemes and confound attempts to evaluate their wider impacts" (Melia and Calvert, 2021, p. 8). By seeking to evaluate the traffic impacts of multiple tactical urbanism interventions during the COVID-19 pandemic in the centre of Barcelona, the present study hopes to provide a significant contribution to this topic.

3. Methodology

The research method presented in this article involves the analysis of temporal changes in permanent traffic count data, through a comparison of *pre-* and *post-intervention* traffic counts. At an empirical level, this analysis relies on the availability of a city-wide historical dataset of permanent traffic count data, often publicly available from municipal open data repositories. For each individual traffic counter, this data is usually provided in the form of average daily traffic (ADT), sometimes further summarised into weekly or monthly daily average traffic (MADT).

Importantly, the presented method does not only examine traffic changes in streets affected by tactical interventions, but also in streets in the wider neighbouring area, as well as in the rest of the city. This makes it possible to explore *relative* changes in traffic levels between various street categories, and identify potential traffic displacement from intervention streets to other street categories. This method is premised on the classification of traffic counting stations into four distinct categories, corresponding to four different street typologies (for a map showing the distribution of these categories in the specific case study of Barcelona, see Fig. 3 in Section 4.3):

- **Intervention** street: This category includes traffic counters on streets which have been directly affected by street redesign or tactical urbanism interventions, resulting in the reduction of at least one traffic lane.
- **Adjacent** street: This category includes traffic counters on parallel streets adjacent to intervention streets running in the same direction, which provide likely alternative routes for traffic.[1]
- **Buffer** area: This category includes all remaining traffic counters within a 500 m distance from tactical urbanism interventions,[2] excluding traffic counters already included in the two previous categories. The rationale behind this category is to explore potential traffic displacement not only on parallel adjacent streets, but also in the wider vicinity of tactical urbanism interventions.
- **Control** area: This category includes all traffic counters on streets in rest of the city (excluding urban highways), beyond a 500 m distance from streets affected by tactical urbanism interventions. This category acts as a control group in relation to the previous three categories, providing a baseline rate of temporal changes in traffic counts for the rest of the city.

Fig. 1 visually summarises the main steps of the research method, which involves a combination of GIS mapping, data processing and visualisation (in the present article, a combination of QGIS and R was used). When comparing the evolution of traffic counts between street categories, the results can be presented (Step 4) both in the form of aggregate counts across multiple traffic count stations, and single-station averages for each street category. While aggregate counts are useful in providing an estimate of absolute changes in traffic levels for each street category, the large difference in the number of traffic stations in each category means that single-station averages allow for a better comparison between street categories.

4. Application to a case study: tactical interventions in Barcelona

4.1. Barcelona's Eixample and superblocks scheme

The regular grid city of Barcelona's *Eixample* district is well known among urban planners as one of the most prominent examples of 19th-century urbanism. In many ways, the *Eixample* of Barcelona provides a good case study to explore changes in traffic levels following the reallocation of road space, since most of its streets follow an isotropic grid layout and share similar fundamental characteristics (e.g. width, traffic speed, number of lanes), thereby facilitating comparisons between streets. In addition, this grid layout makes it easy to identify parallel alternative routes, although it potentially also makes it more difficult to clearly delimit the boundaries of the study area.

As a result of Barcelona's high population density – which is highest in the *Eixample* (36.267 pop./km^2) in 2020) – the city allegedly has the "highest car density in Europe" according to the local municipality.[3] Regardless of the accuracy of this claim, it is undeniable that most streets in the *Eixample* district support high levels of through traffic, with traffic-calmed streets being almost non-existent. These high traffic intensities are responsible for serious negative local externalities such as noise and air pollution, as well as a lack of public open space within the district (Mehdipanah et al., 2019; Mueller et al., 2020). In recent years, the *Eixample* has served as the reference case for developing the "superblock" model of traffic calming, which has received considerable attention in international media and urban planning circles (e.g. Bausells, 2016; O'Sullivan, 2020). Put briefly, the original superblock model (Rueda, 2019) amalgamates nine individual city blocks (3 × 3) and confines through motor traffic to the outer edges of the resulting "superblock", leading to the near-pedestrianisation of the street segments within the superblock. In doing so, the superblock model seeks to significantly curtail overall traffic levels.

The first official superblock in Barcelona was implemented in 2017 in the neighbourhood of Poblenou followed by the more recent interventions in the Sant Antoni area (in the *Eixample* district). While the original aspiration was to extend this model throughout the rest of the *Eixample*, significant opposition to this plan has since led to a less ambitious, more pragmatic plan in an attempt to increase political and social consensus. In effect, the current long-term traffic calming strategy for the *Eixample* moves away from the literal concept of superblocks towards the idea of "green corridors", i.e. the pedestrianisation of specific streets along their full length rather than multiple streets in a specific area. Nevertheless, the "superblocks" label has been retained to refer to the collection of traffic calming interventions and street redesigns which fall under this long-term strategy.

While academic research on Barcelona's superblocks has recently begun to emerge (e.g. Mehdipanah et al. (2019) and Mueller et al. (2020) on public health impacts; Scudellari et al. (2020) and Zografos et al. (2020) on politics and governance), there still appears to be a lack of studies seeking to assess their impacts on local mobility patterns. A recently published technical report by the Municipality of Barcelona,[4] however, estimated that average daily traffic (ADT) in the Sant Antoni superblock diminished by 15 % between 2017 and 2019, and by 21 % between 2017 and 2022.[5] While traffic decreased most markedly on the main intervention street, traffic counts also decreased slightly on

[1] In the case study of Barcelona, adjacent streets which themselves have also been subject to tactical urbanism interventions have been excluded from this category, since they are already included in the *intervention street* category.

[2] The size of this buffer (500 m) has been designed taking into account the urban and street density of Barcelona, but alternative buffer sizes might be more suitable for more or less dense urban environments (e.g. suburban neighbourhoods with a sparser street network).

[3] Municipality of Barcelona, 2016. https://ajuntament.barcelona.cat/eixample/ca/noticia/sabies-que-barcelona-es-la-ciutat-deuropa-amb-mes-densitat-de-vehicles_403904.

[4] Municipality of Barcelona, 2022. https://ajuntament.barcelona.cat/superilles/sites/default/files/2022–03-28_ESTUDI_IMPACTE_MOBILITAT_2023_TOM_I_web.pdf.

[5] This rate of change includes both traffic flows on the main intervention street and on the two adjacent parallel streets in the same direction.

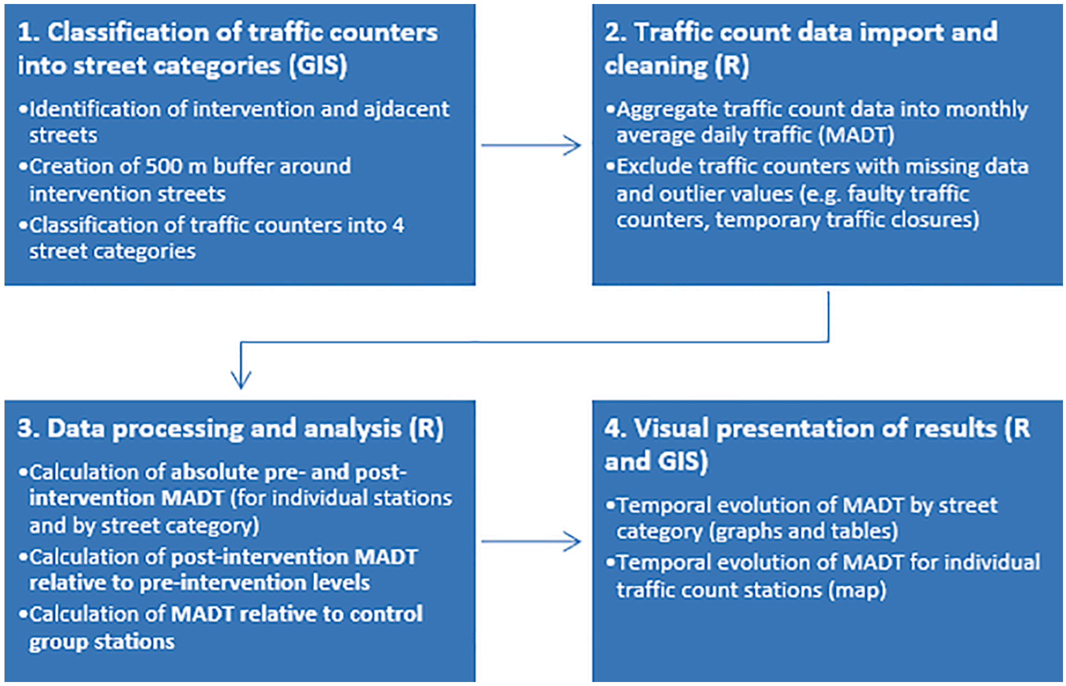

Fig. 1. Visual summary of the research method, broken down into discrete steps.

adjacent parallel streets on either side, suggesting that some degree of traffic evaporation has taken place.

4.2. Tactical urbanism interventions during COVID-19 pandemic

The unexpected onset of the COVID-19 pandemic in early 2020 entailed a major disruption to urban travel patterns worldwide (Abduljabbar et al., 2022). In most cases, travel demand plummeted because of lockdowns and mobility restrictions; owing to the fear of contagion, this reduction in trips was particularly severe in the case of public transport, and entailed a relative modal shift towards active and motorised private transport (Coppola and De Fabiis, 2021; Gkiotsalitis and Cats, 2021). Although travel demand has gradually recovered since the end of pandemic restrictions, it is likely that some structural changes in urban mobility patterns will remain. In particular, travel demand for private modes generally appears to have recovered to a greater extent than for public transport (Abduljabbar et al., 2022), while increased teleworking may contribute to an overall reduction in travel compared to pre-pandemic values (Möllers et al., 2022).

In turn, the COVID-19 pandemic acted as a major stimulus or "window of opportunity" for the implementation of tactical interventions seeking to prioritise active travel modes in urban space in cities worldwide (Glaser and Krizek, 2021; King and Krizek, 2021; Rojas-Rueda and Morales-Zamora, 2021). In Europe, cities like Paris, Milano, Berlin or Barcelona rolled out new "pop-up" bike lanes and closed down streets to motor traffic, as prominently reported in international media (Laker, 2020; Zafra et al., 2020). Subsequently, many of these emergency measures have been made permanent (Fenu, 2021). These measures sought to facilitate social distancing by increasing the amount of public space and providing active travel alternatives to public transport, as well as to try and curb a potential increase in private motorised vehicle use in the wake of the COVID-19 pandemic. Nevertheless, many cities also used the pandemic as an occasion to accelerate various plans which already formed part of their long-term policy vision (Glaser and Krizek, 2021), taking the opportunity to push forward schemes which might have encountered greater resistance during "normal" times.

In Spain, a state of alarm which imposed a strict lockdown was declared on 14 March 2020 as a response to the COVID-19 pandemic, during which people were only allowed to go outdoors to travel to work and undertake other essential trips. These measures were gradually relaxed from May 2020 onwards, but successive COVID-19 waves resulted in the reintroduction of new restrictions from October 2020, including variable degrees of travel restrictions between municipalities/counties, and night-time curfews. All in all, complete normality was only regained on 9 May 2021, when the state of alarm was suspended and all domestic travel restrictions were lifted.

At the height of the pandemic (spring 2020), the municipality of Barcelona announced various emergency measures which entailed the reallocation of road space on multiple streets from motorised traffic to active and public transport, primarily in the central *Eixample* district. These measures sought both to respond to the exceptional context of the pandemic and to advance the underlying urban mobility vision of the city administration, which aspires to reduce the prominence of motorised traffic in the city centre through the implementation of "superblocks" and "green corridors". Largely adhering to tactical urbanism principles and elements (e.g. use of paint and cement blocks), most of these interventions were carried out speedily compared to normal street redesigns. The bulk of these interventions were carried out in May 2020, with a small number of them being announced and implemented later in 2020 and early 2021.

Table 1 lists all streets in the *Eixample* district which experimented notable tactical urbanism interventions during 2020 and early 2021 in the context of the COVID-19 pandemic, which provide the empiric focus of the present study[6] (for a visualisation of these interventions on a map, see Fig. 3 in Section 4.3). In all cases, the reallocation of road space following these interventions resulted in the reduction of at least one conventional traffic lane. It should also be noted that in cases where only one traffic lane remained after the street redesign, speed limits were automatically reduced from 50 to 30 km/h (even though this limit is rarely enforced in practice). While in certain cases the "tactical" nature of these interventions is apparent (e.g. new tactical sidewalks), in other

[6] As an exception, two streets for which no traffic count data was available (Rocafort and Castillejos) were excluded from the analysis.

Table 1
List of street interventions assessed in the present study.

Street	Traffic lanes pre-intervention	Traffic lanes post-intervention	Traffic lane reduction	Execution period	Number of traffic counters
Consell de Cent	2 traffic lanes + bike lane	1 traffic lane + bike lane + tactical sidewalk	1	May 2020	1
Girona	2 traffic lanes + bike lane	1 traffic lane + bike lane + tactical sidewalk	1	May - June 2020	1
Roger de Llúria	3 traffic lanes + bus lane	2 traffic lanes + bus lane + bike lane	1	May 2020	2
Pau Claris	3 traffic lanes + bus lane	2 traffic lanes + new bike lane (+bus lane)	1	May 2020	3
Aragó	6 traffic lanes	Stage 1: 5 traffic lanes + bus lane; Stage 2: 4 traffic lanes + bus lane + bike lane	2	November 2019 (Stage 1); November -December 2020 (Stage 2)	6
Indústria	2 traffic lanes + bus lane	2 traffic lanes	1	May 2020	1
Gran Via	4 traffic lanes + bus lane	3 traffic lanes + 2 bus lanes	1	November-December 2020	3
València	3 traffic lanes + bus lane[1]	2 traffic lanes + bus lane + bike lane	1	May 2020	7
Ronda Universitat	4 traffic lanes + 2 bus lanes	2 traffic lanes + 2 bus lanes	2	November 2020-April 2021	1
Plaça Universitat	4 traffic lanes	3 traffic lanes	1	November 2020-April 2021	1
Pelai	3 traffic lanes + 1 bus lane[2]	2 traffic lanes + 1 bus lane	1	March 2021	2

[1] Part of València Street has a car parking lane on it, so only had 2 conventional traffic lanes prior to the intervention.
[2] Part of Pelai Street only had conventional 2 traffic lanes prior to the intervention.

cases (e.g. new bike lane construction) these measures differed little from similar past schemes, beyond the speediness with which they were implemented. Fig. 2 shows the example of Girona Street before and after the implementation of a tactical sidewalk, which entailed the elimination of one traffic lane and on-street car parking.

4.3. Results

Following the previously described research method, the traffic impacts of the tactical interventions listed in Table 1 were assessed using publicly available permanent traffic count data published by the Municipality of Barcelona for the years 2019–2021.[7] For each individual traffic counter, the municipality provides this data in the form of monthly average daily traffic (MADT) by type of day (Monday/Weekday/Friday/Saturday/Sunday), from which a global MADT was calculated for each traffic counter.

Fig. 3 maps all street interventions listed in Table 1, and shows the classification of traffic counters according to the four street categories described in the Methodology (the total number of traffic counters in each category is displayed in the map legend). All traffic counters with available data for all years were included in the analysis, except for three counters which were significantly affected by a temporary traffic diversion following roadworks on a section of Avinguda Diagonal in 2021. For these three locations, preliminary results showed that traffic counts deviated largely from usual values because of traffic rerouting during much of 2021, leading to their exclusion from the analysis.

Given the large fluctuations in traffic values during 2020 and early 2021 as a result of COVID-19 restrictions, the main analysis has been restricted to two distinct time periods, which also largely correspond with pre-and post-pandemic stages: namely, the 2nd semester of 2019 (pre-intervention), and the 2nd semester of 2021 (post-intervention). As part of the exploratory analysis, I also examined differences in results by day of the week (weekday vs weekend), but have not included these in the results, since they did not reveal any noteworthy pattern.

To contextualise the results, Fig. 4 shows the evolution of the average single-station MADT for all traffic count stations in Barcelona for the years 2019–2021. As can be seen, traffic counts decreased dramatically in early 2020 as a result of COVID-19 lockdown, and remained significantly below 2019 values for the rest of 2020 and early 2021. By the second half of 2021 traffic was closer to, but still somewhat below 2019 values.

In Fig. 5, I display the evolution of average single-station MADT from the beginning of 2019 to the end of 2021 according to the four previously defined street categories. This figure shows that traffic counts have decreased most markedly for intervention streets; for the three remaining categories, the evolution in traffic counts appears to be relatively similar, pointing to a slight reduction in traffic levels over the period under consideration. Although the effects of seasonality and COVID-19 restrictions (particularly for the lockdown during April-May 2020) are similar for all street categories, the linear trend for each category (discontinuous line) clearly evidences that traffic counts on intervention streets have decreased more pronouncedly than for the other three categories.[8]

The relative evolution of traffic levels between street categories can be visualised more clearly by examining how traffic counts have evolved *relative to the 2019 annual average* for each category, as displayed in Fig. 6. This graph shows that traffic counts have recovered at a similar rate after COVID-19 restrictions for all street categories except for intervention streets, for which traffic counts have recovered at a significantly slower rate relative to 2019 values. By December 2021 – the last month with available data – average traffic values on intervention streets had recovered to 82 % of the 2019 annual average on intervention streets, compared to 92 % on both adjacent and buffer streets, and 95 % on control streets.

Critically, the significant reduction in traffic counts on intervention streets does not appear to have caused a commensurate increase in traffic counts in adjacent and buffer streets compared to streets in the control group. As shown in Figs. 5 and 6, the overall evolution of traffic levels is very similar for the adjacent, buffer and control categories (in fact, Fig. 6 suggests that traffic levels during the second half of 2021

[7] Yearly traffic count data sets can be found at the city's Open Data portal: https://opendata-ajuntament.barcelona.cat/data/ca/dataset/aforaments-detall.

[8] As a clarification, the reason why average traffic counts are highest on intervention streets is simply that these interventions took place on streets with higher traffic values than the city average.

Fig. 2. Girona Street before and after the implementation of a new tactical sidewalk (Source: Google Street View/author).

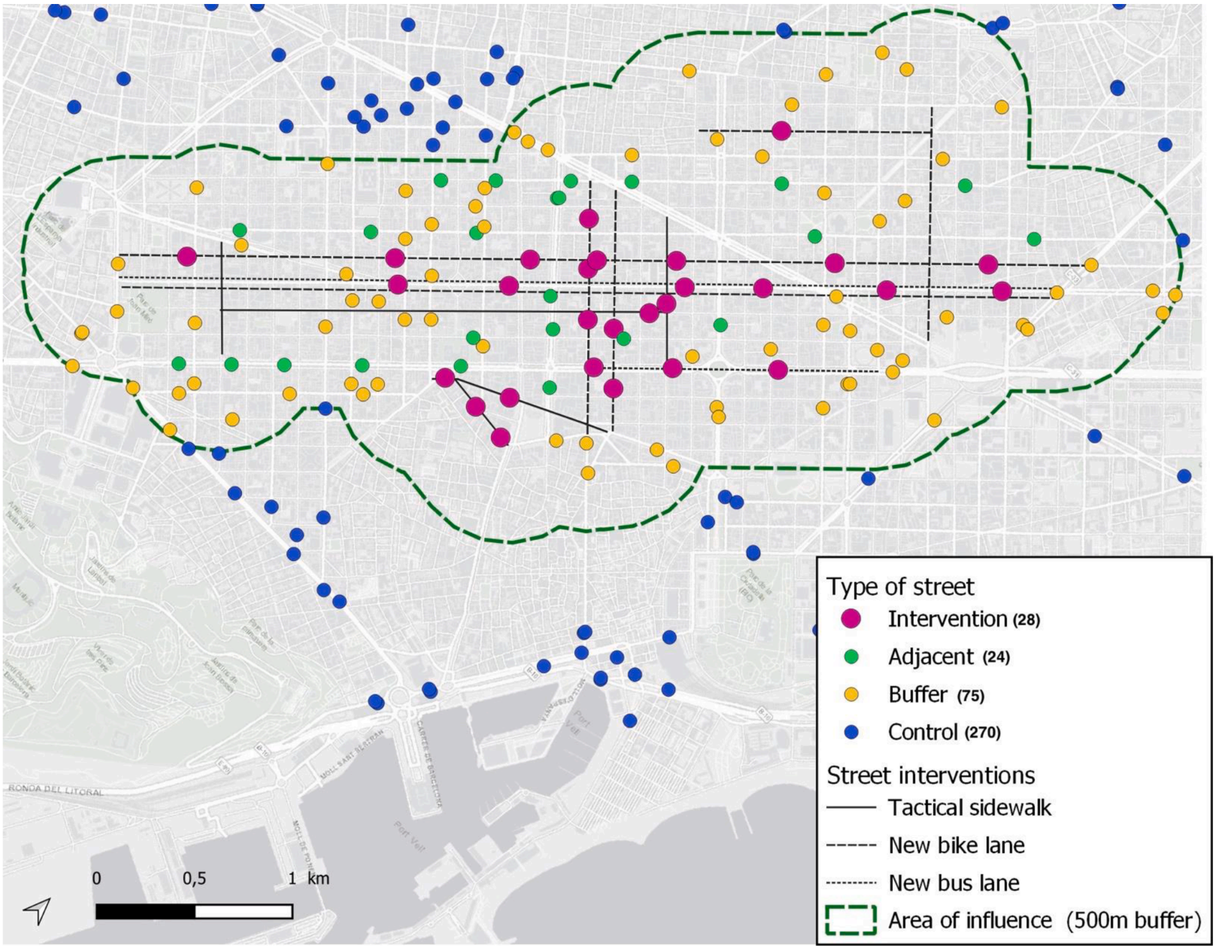

Fig. 3. Street interventions and traffic counters by category. Note: Most traffic counters in the control street category are situated beyond the boundaries of the map (up to the municipal limits of the city).

relative to 2019 are even somewhat lower on average for adjacent and buffer streets than for control streets). This can be seen by visually comparing the evolution of traffic counts *relative to the control group* for the remaining three street categories (Fig. 7). As illustrated in previous graphs, this figure confirms that relative traffic counts have clearly decreased in intervention streets. However, the most noteworthy finding is that the trend line for the parallel and buffer street categories is essentially flat or even slightly negative relative to the control group category. If traffic from intervention streets had been largely displaced to adjacent streets and the wider neighbouring area, one would expect to see a positive trend line. Instead, these results show that *traffic levels have declined in intervention streets without causing a corresponding traffic increase in their vicinity*, thereby suggesting that a significant amount of traffic evaporation has taken place.

As a complement to the above graphs, Table 2 provides a numerical summary of the relative evolution of average traffic counts between the second semester of 2019 (pre-intervention) and the second semester of 2021 (post-intervention) for each street category. This table displays average and median changes in single-station traffic counts between 2019 and 2021 for each category, as well as the total aggregate change for all streets in each category (i.e. sum of individual traffic stations). Table 3 presents the same information for streets in the intervention, adjacent and buffer categories relative to streets in the control group. This table shows that traffic levels between 2019 and 2021 have decreased significantly on intervention streets compared to control streets, with an average relative reduction of −14.8 % (−23.8 % in absolute terms), and a total relative reduction of −13.6 % across all intervention streets. By contrast, traffic levels in adjacent streets show a small relative increase in traffic relative compared to control streets, while traffic levels on buffer streets have evolved almost identically to streets in the control group.

Within-category variability between individual counting stations is displayed in Fig. 8, which provides a box plot of relative traffic count evolution between 2019 and 2021 by street category. As can be seen, variability is greatest within the control group given the large number of counting stations it includes, while outliers within the other three categories are rarer. At the individual street level, estimates of relative traffic change on intervention streets compared to the control category vary between +22 % and −36 % (+13 % and −45 % in absolute terms). Within the intervention street category, only four traffic count stations have experimented a relative increase in traffic counts compared to the control group. Three of these four traffic count stations were these situated on the same street (Gran Via), which differs from most other intervention streets because of its uniquely large width and number of traffic lanes (see Table 1). As already shown in Table 3, the box plot highlights that traffic levels on most adjacent streets have increased slightly compared to the streets in the control group, while most streets in the buffer category have experimented a small relative decrease.

Further information on the evolution of traffic counts at an individual station level is presented in the map in Fig. 9, which displays the relative change in MADT for traffic stations in the intervention (□), adjacent (△) and buffer (○) street categories compared to control group streets. While this study does not seek to examine changes in traffic counts on a street-by-street basis, the map confirms that traffic levels have generally evolved in the same direction for counting stations on the same street. Considering all three street categories together

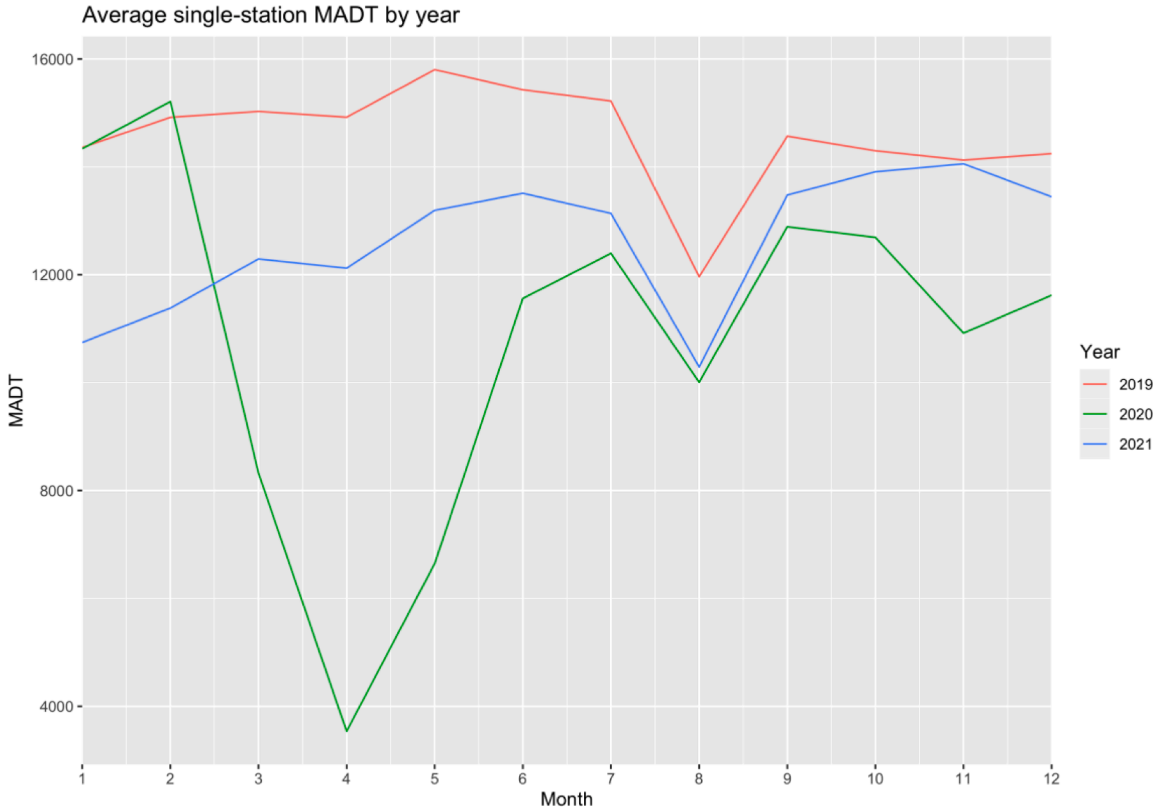

Fig. 4. Average single-station MADT by year.

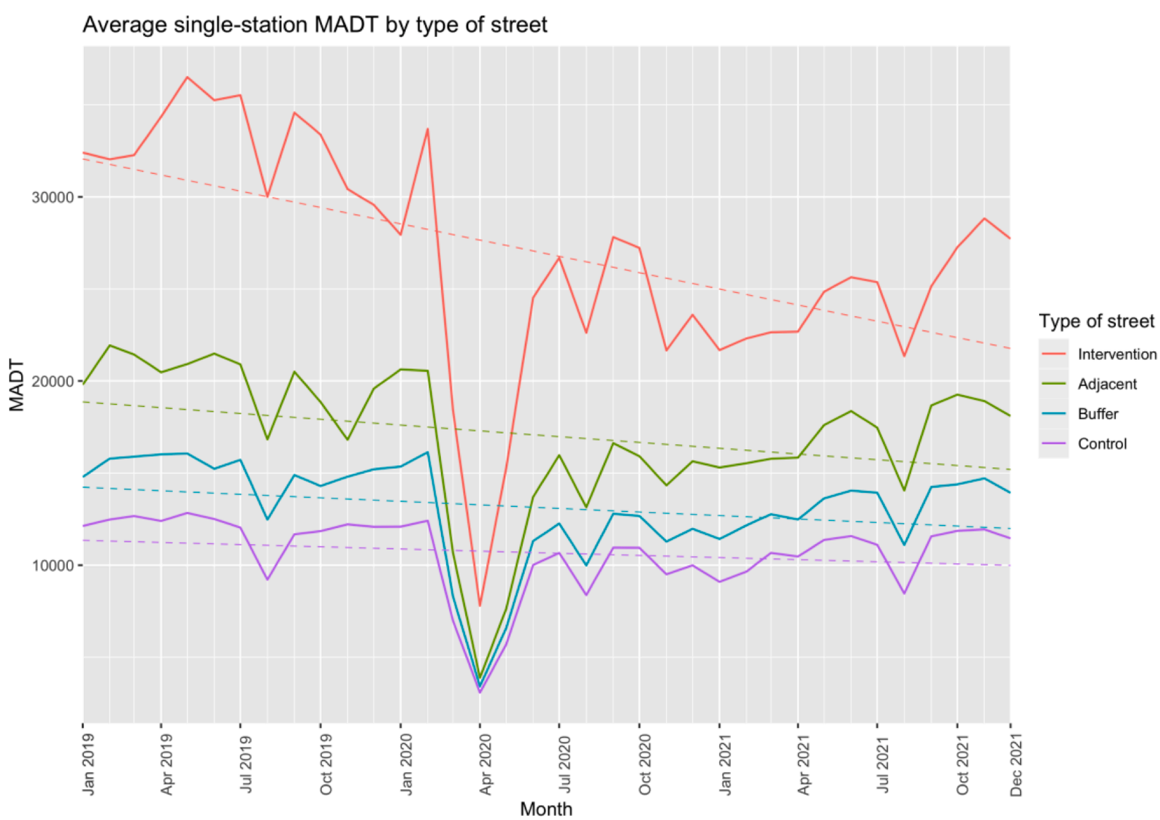

Fig. 5. Average single-station MADT by type of street.

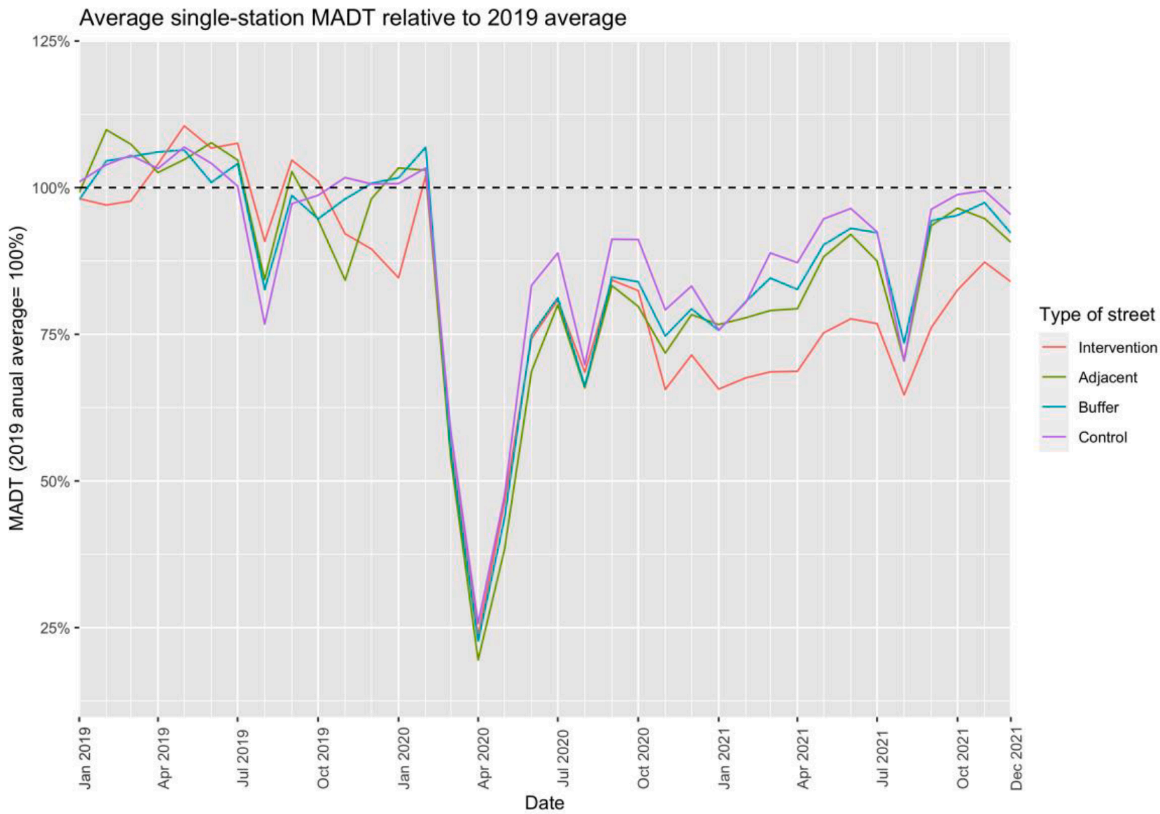

Fig. 6. Average single-station MADT by type of street relative to 2019 annual average.

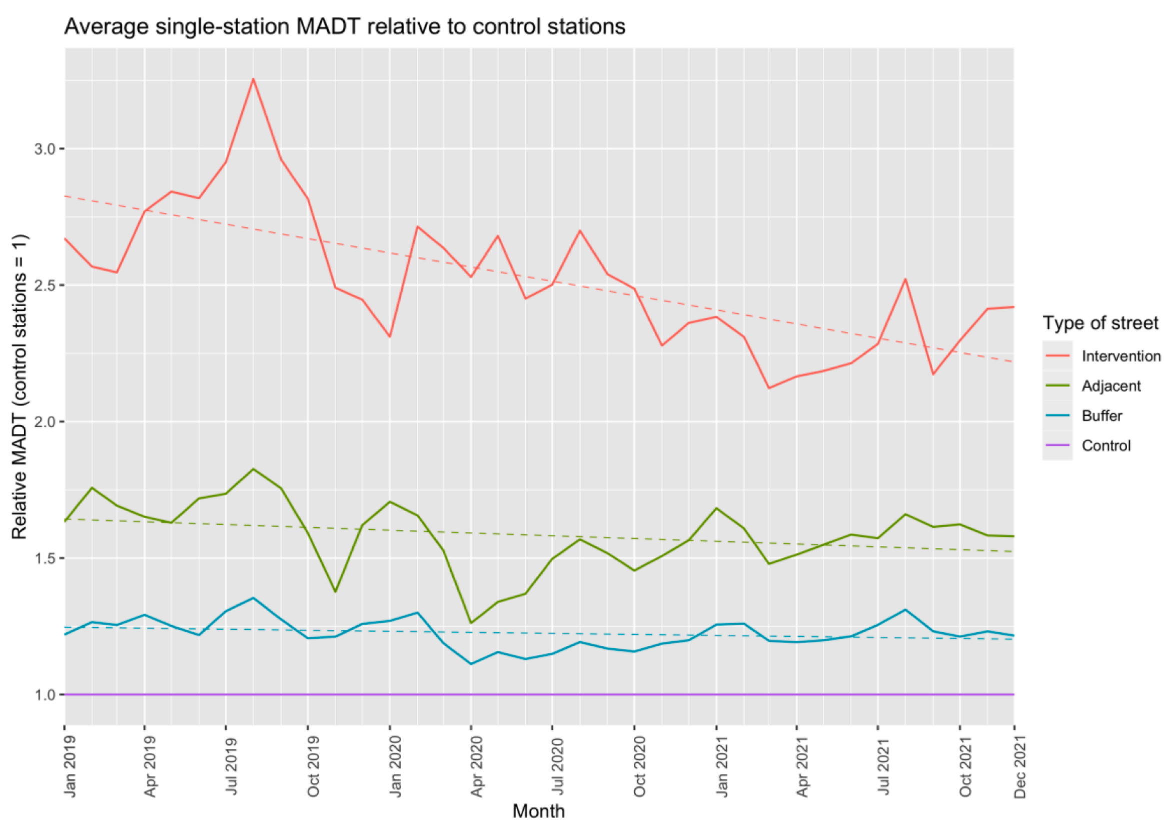

Fig. 7. Evolution of average single-station MADT relative to control stations.

Table 2
Absolute traffic count evolution by street category (2nd semester 2019–2nd semester 2021).

Type of street	Average	Median	Total
Intervention	−23.8 %	−24.8 %	−23.3 %
Adjacent	−8.3 %	−5.5 %	−7.2 %
Buffer	−9.5 %	−10.5 %	−8.7 %
Control	−9.1 %	−9.4 %	−9.7 %

Table 3
Relative traffic count evolution by street category compared to streets in the control group (2nd semester 2019–2nd semester 2021).

Type of street	Average	Median	Total
Intervention	−14.8 %	−15.4 %	−13.6 %
Adjacent	+0.7 %	+3.9 %	+2.4 %
Buffer	−0.4 %	−1.1 %	+1.0 %

(intervention, adjacent and buffer), relative traffic levels have decreased in 77 of 127 stations within the area of influence in Fig. 9, with the remaining 50 stations experimenting a relative increase compared to the control group. Overall, total traffic levels (sum of individual station averages) within the area of influence have decreased by −4.1 % between 2019 and 2021 compared to the rest of the city (i.e. control group stations).

5. Discussion

Overall, the results of the analysis show that traffic levels have diminished significantly on intervention streets (−23 % in absolute terms, and −14 % relative to the rest of the city), without causing a substantial increase in the neighbouring area. While traffic calming schemes can potentially lead to the emergence of "loser" streets adversely affected by traffic displacement (Appleyard, 1981), in the present case study adjacent streets only experienced small relative increases in traffic (+2%). This suggests that rather than causing widespread traffic displacement, the interventions under study been led to a significant "evaporation" of traffic.

Although comparing between studies requires caution given the different temporal scale and geographical setting of each study, it is interesting to note that average that the median relative traffic reduction across all intervention streets in the present study (−15.4 %) is quite similar to the median reduction of −11 % reported in the review of 70 cases by Cairns et al. (2002), and within the same order of magnitude than the observed reductions from other studies which entailed the partial removal of car lanes (e.g. −4.2 % in Bucsky and Juhász (2022); −23 % in Tennøy and Hagen (2021)). This suggests that although it may be difficult to accurately model or predict exact levels of traffic reduction, it is not unreasonable to venture an educated guess about the direction and magnitude of traffic changes to expected following road space reallocation measures.

Admittedly, the findings of the present study cannot be fully separated from context of the COVID-19 pandemic and the overall reduction in urban travel demand in its aftermath. Given the recent implementation of the tactical urbanism schemes under examination, this study only assessed their implications over a relatively short term (<1 year), in a context where traffic levels have not yet entirely recovered to pre-pandemic values. In this respect, the COVID-19 pandemic paradoxically provided the conditions which allowed for the implementation of tactical interventions, but also made it more difficult to evaluate their effect. Since the pandemic entailed a significant disruption of daily mobility patterns which resulted in a global temporary reduction of motorised traffic, it is virtually impossible to assess the immediate short-term impacts these interventions would have had under "normal" conditions. Although daily mobility patterns had largely gone back to usual

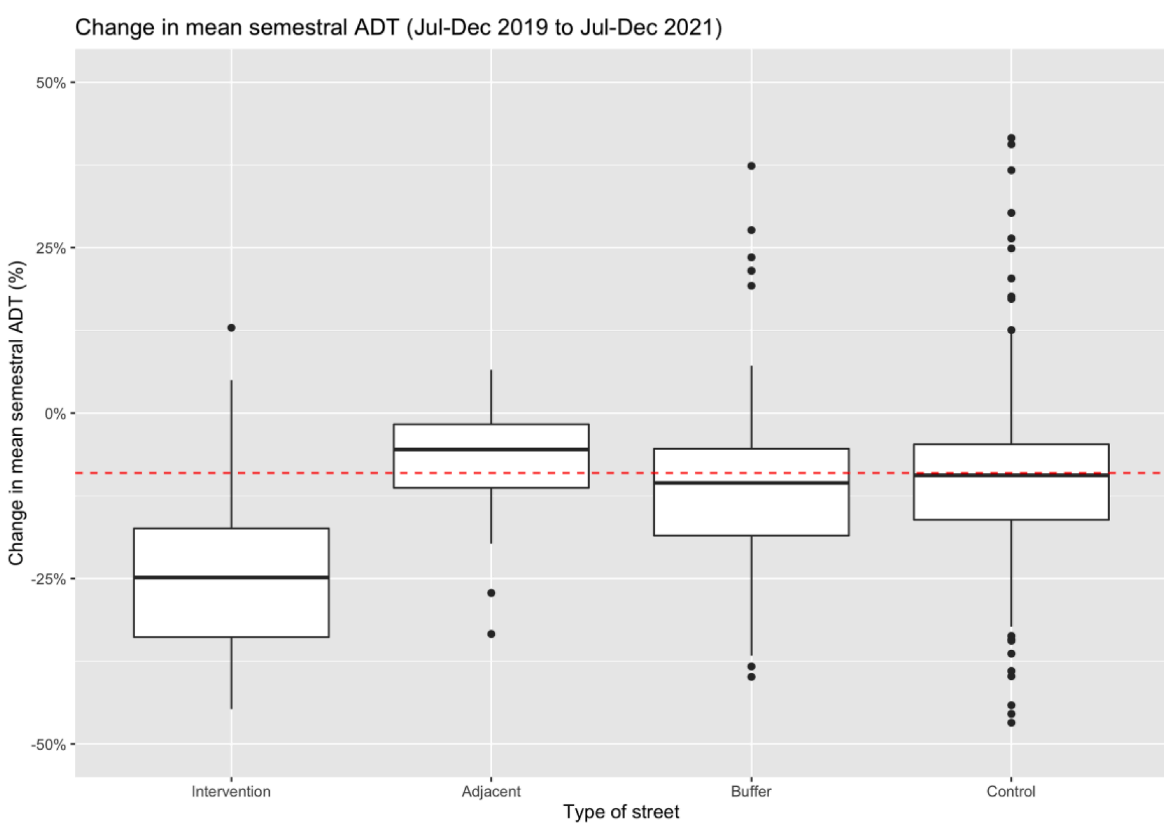

Fig. 8. Change in mean semestral ADT by street category (Jul-Dec 2019 to Jul-Dec 2021). The red line indicates the average for the control group category. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

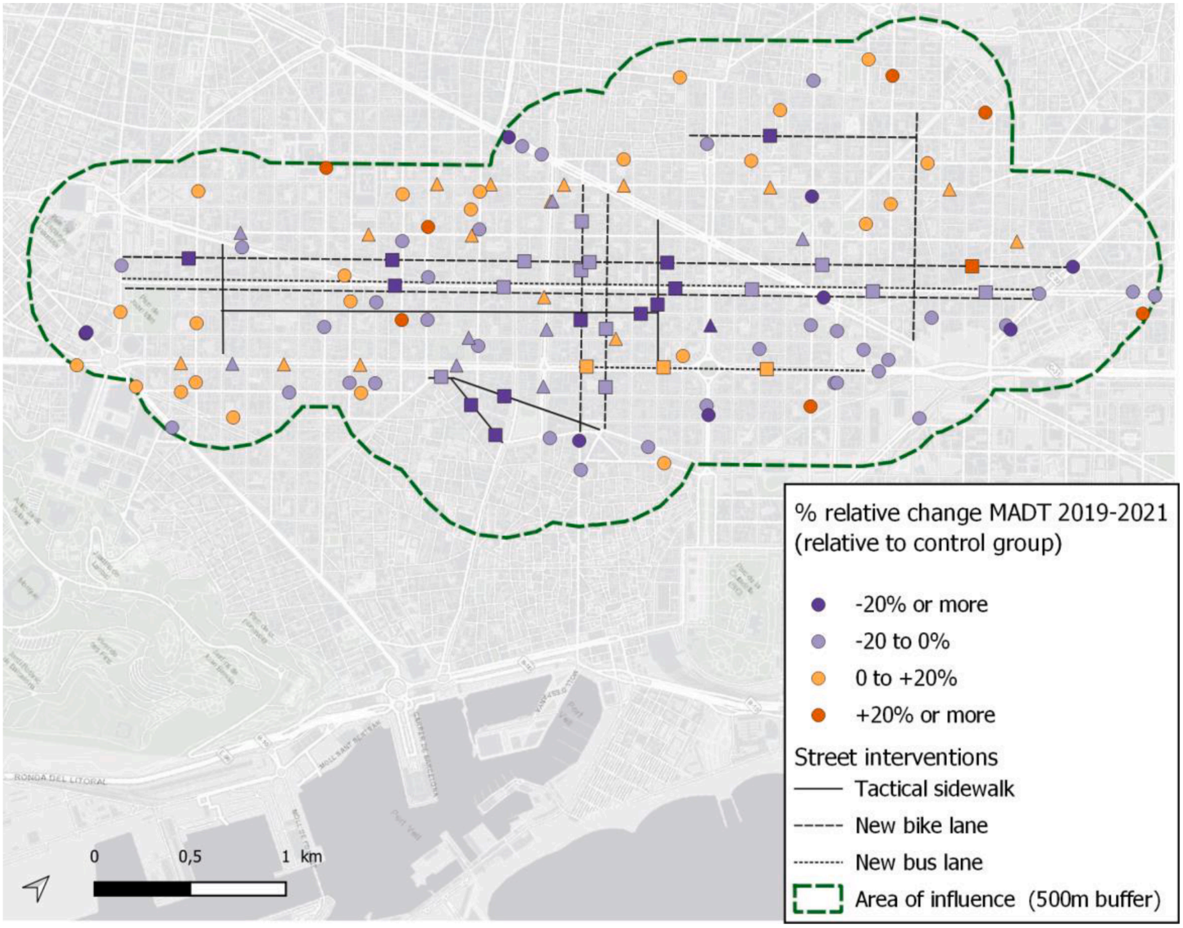

Fig. 9. % change in MADT for individual traffic counters in intervention (□), adjacent (△) and buffer (○) streets relative to control group stations (Jul-Dec 2019 to Jul-Dec 2021).

by the second semester of 20201, traffic levels remained below pre-pandemic levels by the end of 2021, making it difficult to assess absolute levels of traffic evaporation (since traffic has "evaporated" everywhere, so to speak). For this reason, the paper has focused on assessing *relative* traffic evaporation on intervention streets, compared to control group streets. While this inevitably limits the scope of the findings, it nevertheless provides a way forward to evaluate changes in traffic counts in the light of the COVID-19 pandemic. Given the enduring prominence and relevance of public debates on this topic, being able to partially evaluate the effects of street space reallocation measures during the pandemic certainly seems preferable to not doing so at all.

This focus on relative rather than absolute traffic changes, I suggest, is not only valuable in the context of the COVID-19 pandemic, but might contribute to provide a more suitable way of assessing traffic evaporation more generally. Traffic levels are rarely static, but fluctuate over time in response to influences such as temporary road closures, new measures which might affect traffic levels (e.g. congestion charges, low emissions zones), and long-term trends (e.g. decreasing car use in urban areas, economic cycles). As a way of overcoming this difficulty, I propose that focusing on *relative* traffic changes on intervention streets compared to control group streets may provide a more rigorous way of assessing traffic evaporation.

Regarding the possible causes of traffic evaporation, existing studies suggest that it can be attributed to a combination of modal shift, trip suppression and changes in trip destination (Hunt et al., 2002; Melia and Calvert, 2021; Zhu et al., 2010). While the present study is unable to investigate the relative role of various factors in explaining traffic evaporation, in the context COVID-19 pandemic and its aftermath it seems plausible to ascribe most of the "evaporated" traffic to suppressed trips. Indeed, the rise of teleworking has been one of the main legacies of the COVID-19 pandemic, both in Barcelona (Andrés et al., 2021) and worldwide (Möllers et al., 2022). The *Eixample* is a pre-eminently central mixed use district, characterised by an important concentration of office spaces, tertiary services, and predominantly white-collar residents, suggesting that it is one of Barcelona's neighbourhoods where reduced travel as a result of telework is likely to be most felt. Likewise, the general reduction in tourism in Barcelona in the aftermath of the pandemic might account for part of the "evaporated" traffic. The tactical street interventions under study (and the COVID-19 pandemic more broadly) may have also led to some modal shift towards active travel, and cycling and e-scooter use in particular, which in the metropolitan area of Barcelona saw a +4.3 % rise in usage between 2019 and 2020 (Andrés et al., 2021). Public transport provision in the Eixample district (and Barcelona more generally), meanwhile, has not varied significantly between 2019 and 2021, and public transport demand continued to be at approximately 75–80 % of its pre-pandemic level by the end of 2021.[9] In this respect, there is little evidence which suggests a modal shift from motorised to public transport.

Finally, it is important to be aware that numerical traffic counts in the form of ADT these are a useful but nevertheless simplistic indicator of changes in traffic. For residents and transport planners alike, alternative measures such as traffic speeds, congestion levels, environmental

[9] This data on public transport demand is published by the Metropolitan Transport of Barcelona (ATM) as part of a COVID-19 interactive dashboard: https://datastudio.google.com/u/0/reporting/8134194c-db6d-4d6a-ac8b-fd5e34dbfc4d/page/oWSOB.

and acoustic pollution, or traffic accidents might often provide more relevant metrics than simple traffic counts to assess traffic changes at a given location. Furthermore, ADT counts usually focus exclusively on motorised traffic, ignoring other means of transport such as cyclists, pedestrians, electric scooters, or bus users. In the present study, for instance, reductions in conventional traffic lanes were accompanied by new cycling and bus lanes on various streets. Although beyond the scope of the present study, exploring how the use of these other transport modes has changed as a result of street interventions (e.g. cyclist counts, bus occupancy rates) would contribute to deliver a fuller picture of their effect on street-level mobility.

To close, I would like to note two additional limitations of the present study. As mentioned previously, the analysis relies on publicly available traffic count data which was not collected for the specific goals of the present study. Although the spatial coverage of municipal traffic counting stations is extensive, there are certain relevant streets for which no data is available. In this respect, a targeted data collection scheme for this specific purpose would be able to deliver more precise results. Secondly, and given the relatively extensive study area and time period considered, the study does not account for all small temporary road closures and other street-level disruptions which might introduce some level of noise into the data at the level of individual traffic counting stations.

6. Conclusion

The present study has examined the impact on traffic levels of tactical urbanism interventions implemented during COVID-19 pandemic on 11 streets in *Eixample* district in Barcelona, which led to the reduction of one or more traffic lanes on each street. The findings show that between 2019 and 2021, total traffic levels on intervention streets decreased by −23 % in absolute terms, and by −14 % compared to control group streets (i.e. streets in the rest of the city). Although total traffic levels relative to streets in the control group increased slightly for parallel streets immediately adjacent to intervention streets (+2%), traffic in other streets within the wider vicinity of the intervention area (500 m buffer) did not evolve significantly differently to streets in the control group. Overall, these results suggest that significant traffic evaporation has taken place in streets where tactical urbanism interventions were implemented, without leading to a corresponding increase in traffic within streets in their vicinity. While there is evidence of some local traffic displacement from intervention to adjacent streets, the level of relative traffic increase on adjacent streets is much less than the corresponding decrease in traffic on intervention streets.

At a theoretical and empirical level, this article contributes to the growing critical mass of studies which provide empirical evidence of traffic evaporation. More specifically, the present study represents one of the first attempts to evaluate the traffic impacts of tactical urbanism measures adopted during the coronavirus pandemic in a rigorous and transparent manner. By providing a detailed explanation of the methodology used, this study presents a step forward towards developing a transparent way of evaluating traffic reduction schemes, which might serve as an example for future studies. In this respect, the increasing availability of traffic count data in municipal open data databases offers an opportunity for replicating the methodology of the present study in a different setting.

In terms of future research, it would be interesting to carry out a follow-up study of the present case study in a few years. By then, various of the current tactical street redesign measures are set to be replaced with permanent street redesigns, and complemented with further traffic reduction measures as part of the roll-out of proposed superblocks plans in Barcelona. Another important methodological challenge which future research could seek to address is the difficulty of disentangling the effects of multiple neighbouring interventions. Given the relative proximity and temporal simultaneity of all interventions in the present case study, I opted to consider them largely as a single whole, focusing on their cumulative effect within the whole study area. Nevertheless, this makes it difficult to assess the effect of each individual intervention. In future research, it would be interesting to explore the extent to which the effect of isolated interventions is comparable to that of multiple interventions. Finally, and as pointed out in the discussion, focusing not only on traffic counts but also on other complementary dimensions (e.g. traffic noise, pollution, speed, pedestrian counts) would represent an important step forward towards a more holistic assessment of the implications of road space reallocation schemes.

Author contributions

Samuel Nello-Deakin: Conception, analysis and writing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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