Journal of Transport & Health 41 (2025) 101984

Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

Policy measures to reduce road congestion: What worked?☆

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ARTICLE INFO

Keywords:
road transport
road congestion
transport policy
travel behaviour

ABSTRACT

Background: Road congestion is a persistent problem. Increasing road capacity has not solved this problem, which requires measures to curb road use demand. This paper reviews recent evidence on the effectiveness of different types of policy measures in reducing congestion through reducing road use. The paper answers three questions: 1) what explains the success or failure of measures in reducing congestion?, 2) is the reduction of congestion sustained in the long term?, and 3) are combinations of measures more effective than single measures?.
Methods: We searched the literature for studies assessing the effects of policy measures that aimed at reducing congestion through reducing road use demand.
Results: Restrictions to vehicle ownership tend to reduce congestion, but road use charging and vehicle restrictions are not always effective as road users circumvent the charges or restrictions. Soft measures such as incentives and the provision of information have mostly short-term effects. More evidence is needed on measures affecting fuel prices, high-occupancy vehicle lanes, and parking policies. Measures to reduce road use demand are more effective when combined with measures to improve public transport.
Conclusions: Policies to reduce congestion in the long term need to account for possible adaptations in road user behaviour and provide alternatives to road travel.

1. Introduction

Road congestion is a condition when traffic volume approaches the road capacity, increasing traffic density and/or reducing speeds to below the free-flow speed. Exposure to road congestion has been linked to negative mood-states such as stress, anxiety, anger, frustration, and fatigue, which have long-term consequences such as reduced satisfaction with travel, poor mental health and reduced wellbeing (Conçeicão et al., 2023). Congestion also leads to community-wide problems such as reduced economic activity, employment, and productivity (Jin and Rafferty, 2017; Sweet, 2014), and to increased exposure to harmful emissions (Levy et al., 2010), which are then linked with poorer health outcomes.

☆ This paper is a shortened and revised version of "*What interventions are effective in reducing congestion*", a chapter by the same authors published in *Mindell JS and Watkins SJ (2024) Health on The Move 3 – The Reviews, Advances in Transport Policy and Planning Book Series, Elsevier*; with permission of the publishers and the journal and book series editors.

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https://doi.org/10.1016/j.jth.2025.101984
Received 22 April 2024; Received in revised form 30 December 2024; Accepted 3 January 2025
Available online 12 January 2025

The traditional solution to solve congestion has been to build more roads or upgrade existing ones. This solution is still advocated by some transport authorities (UK DfT, 2023) and researchers (Anas, 2023), despite the evidence that increasing road capacity tends to aggravate congestion, rather than mitigating it (Goodwin and Noland, 2003). This was first noted by Bressey and Lutyens (1938) and confirmed in several empirical studies (Duranton and Turner, 2011). As shown by Watkins (2011), an increase in road capacity will have the short-term effect of increasing road travel speeds, leading to more and longer trips and switching of modes and routes. However, in the long term this will influence households' residence location patterns, as it increases the radius of potential commuting areas. More households will choose to live farther away from their workplace as they can access it within an acceptable travel time by private car. However, the result of more households travelling for longer distances is an increase in road traffic volumes. This will occur up to a point where the available road capacity is insufficient to accommodate all users, which means that the road will become congested again. In other words, road use will keep increasing until it reaches an equilibrium point, at which congestion levels are acceptable to just enough potential travellers for the road to accommodate them. Anupriya et al. (2023) confirmed that increasing road network capacity is not an efficient solution to manage congestion, because the average travel speed in the network does not increase substantially due to induced growth in travel volumes. Tennøy et al. (2019) also found that urban road capacity expansion in two Norwegian cities had no effect (or only short-term effect) on congestion relief.

Downs (1962, 2004) suggested that reducing road congestion can only be achieved by improving alternatives to car travel. This was confirmed by Mogridge (1990), who showed that, over the long term, traffic speed in London was more closely linked to the quality of the rail network than to any improvement in road transport, even the replacement of horse-drawn vehicles with motorised vehicles. More recently, the review of Fageda (2021) concluded that light rail systems tend to reduce congestion, confirming Mogridge's findings. However, the review of Duranton and Turner (2011) found no significant evidence that the provision of public transport reduces congestion.

A third solution is to aim for a reduction in the demand for private car use. This can be achieved by "hard measures" such as changes to the road infrastructure or operation (e.g., removing roads or reallocating space from cars to buses, cyclists, and pedestrians), regulations (e.g., banning car traffic in some roads or areas or at some times of day), and economic measures (e.g. road use charging). Reducing private car use can also be achieved by "soft measures" such as information provision and travel incentives attempting to influence people's perceptions and attitudes towards travel. Cairns et al. (2008) reviewed the evidence in the UK, finding that the combination of hard and soft measures reduced road traffic volumes by an average of 10–15%, with the reduction in some cases reaching 15–20%. However, the application of soft measures alone was still effective. For example, school travel plans were linked to reductions of 8–15% in school-run traffic and workplace travel plans to reductions of 10–30% in car commuting.

In sum, there are three different approaches to reducing road congestion: adding more road capacity, improving alternative modes, and discouraging driving, either by reducing the need to travel or by modal shift. While the studies cited above already hint at the ineffectiveness of adding road capacity and the possible effectiveness of the other two strategies, there are several alternatives for improving public transport and for "hard" and soft" measures to reduce demand for car use, and it is expected that not all have the same degree of effectiveness. In addition, in the last 20 years, the range of possible policy measures has increased. For example, technological developments now allow for more targeted methods of electronic road charging.

This paper reviews recent evidence on the effectiveness of different types of policy measures in reducing congestion. In addition, it aims at answering three specific questions.

1. What explains the success or failure of policy measures in reducing congestion?
2 Can the reduction of congestion be sustained in the long term?
3 Are combinations of measures more effective in reducing congestion than single measures?

2. Methods

The review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher et al., 2009). We used the search shown in Table 1 in two general academic databases (Scopus and Web of Science) and in a public health studies database (PubMed). The search strings used defined the scope of the potentially relevant document. The focus is on assessing the effects of specific policy measures that aimed at changing road user behaviour and reducing congestion. The objective was to exclude, as much as possible, studies that did not analyse changes in congestion or that analysed changes in congestion that were not related to preceding policy measures.

Fig. 1 shows the PRISMA flow diagram. All steps in the process were performed by at least two of the three authors, with the third

Table 1
Search criteria.

Criterion	Search String
Review objective	congestion
Transport congestion	(traffic OR transport*)
Studies about policy measures	AND (measure OR policy OR intervention OR manage*)
Measures that change road user behaviour	AND behav*
Measures with specific aims related to congestion reduction	AND (promote OR reduc* OR mitigate* OR alleviat* OR relie* OR worse* OR increase)
Analyses of the impact of policy measures	AND (effect* OR evaluat* OR *assess*)

author resolving any disagreement.

The initial search found 1907 studies, of which 444 were duplicates included in more than one database. We then screened the titles and abstracts of the remaining 1463 studies. This led to the exclusion of a further 1106 studies, judged to be not relevant. The next stage was the review of the full text of the remaining 357 studies. At this stage, we excluded studies that did not fill all the eight criteria below.

1 In English
2. Peer-reviewed
3. Published in the last 20 years (January 2003 to February 2023)
4. Analytical studies, excluding reviews and thought pieces
5. Used real-world before-after data, excluding stated preference surveys, simulations, and forecasting studies.
6. Cover the population of road users in the study area, excluding studies using samples and studies about special trip purposes (e.g. trips to school, emergencies).
7. Evaluated policy measures targeting the reduction of congestion.
8. Evaluated the impact of the policy measures on traffic volume and/or speed.

It should be noted that reducing overall car use/volumes, or increasing traffic speeds, is not the same as reducing congestion, but it is used as a proxy for reduced congestion in many studies. So, we investigated the impact of the policy measures on traffic volume and/or speed to reflect their effectiveness in reducing congestion.

The full-text review led to the exclusion of 336 studies. A total of 21 studies were retained.

We then searched for relevant studies among those that cite or are citied by the selected 21 studies. This returned 213 new studies, which we reviewed using the same process (exclusion of duplicates, title and abstract screening, and full-text review). This led to the inclusion of 29 studies to the original 21, totalling 50 selected studies.

We then reviewed in detail the 50 selected studies, extracting the following information: type of policy measure, area of application, targeted road users, effectiveness in reducing congestion, outcome variable, behavioural change variable, number of research subjects, spatial scope, and type of data collected.

We did not consider quality as a criterion to select studies. However, we assessed quality when deciding which results to include in the description of the results in the following section. We considered risk of confounding, the validity of statistical analysis, and whether the conclusions and policy implications claimed in the paper were consistent with the reported results.

3. Results

3.1. Road use charging

There is a long history of road user charging schemes. Singapore started charging road use in 1975. Several European cities have followed (e.g. London, Milan, Gothenburg, Oslo, Bergen, Trondheim). Most schemes are cordon-based, i.e. drivers are charged when

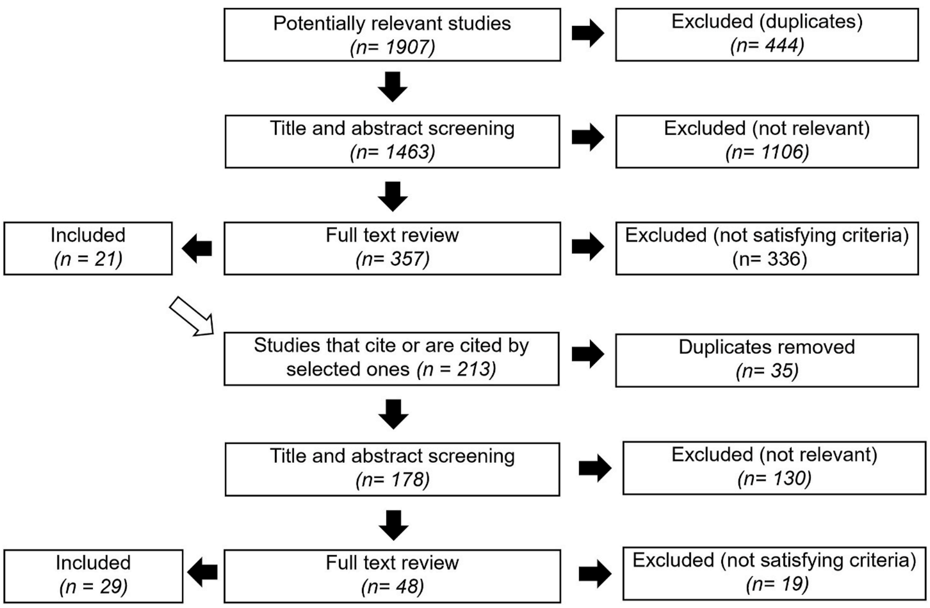

Fig. 1. PRISMA flow diagram.

they cross the cordon, which is usually around the city centre. However, there are some variations in charging method: drivers pay at each toll point they cross or per each time or each day they cross the cordon. The payment is either deducted automatically, paid just before or after the driver crosses the cordon, or processed as a monthly bill. The charge may differ for residents, non-residents, or commercial drivers, or vary by vehicle size. Charging times and days also differ. The specific characteristics of the scheme affect their effects on traffic volumes and speeds (Martin and Thornton, 2017).

Some studies have shown that road use charging can reduce congestion when combined with improvements in public transport. This has been the case in Singapore (Santos, 2005), London (Santos, 2005; Givoni, 2012), Stockholm (Eliasson et al., 2009; Börjesson et al., 2012), Gothenburg (Börjesson and Kristoffersson, 2015), Oslo and Bergen (Lian, 2008) and Milan (Rotaris et al., 2010; Gibson and Carnovale, 2015). These studies found reductions in road traffic volumes in the charged area between 6% and 22%. The extension of the charged area in London reduced road traffic volumes by 5% in the new area, but a subsequent removal of the scheme in that area did not increase traffic volumes to their original levels (Ouali et al., 2021). In Trondheim, when the scheme was removed, traffic increased by 11% (Meland et al., 2010).

The expectation is that individuals respond to road use charging by reducing car use, either by shifting to public transport or reducing the number of trips. However, they can also respond by avoiding the charge (e.g. by not using the charged area or using it during uncharged times). This may lead to an unintended effect of the measure: the increase in congestion in the uncharged areas or times. For example, the Gothenburg road use charging scheme increased traffic volumes on the roads bypassing the charged area (Börjesson and Kristoffersson, 2015). When road use charging was introduced in Singapore, there was a 23% increase in the number of vehicles entering the charged area 20 minutes outside the restricted period (Santos, 2005). If charges differ by type of vehicle, individuals may also start using a different vehicle. For example, Percoco (2014) showed that road charging in Milan did not succeed in reducing the number of vehicles in the charged area but led to a shift towards less polluting vehicles, which were charged less.

When road user charging is applied in tandem with public transport improvements, it is difficult to isolate the role of each of these measures in reducing congestion. For example, the reduction of road traffic volumes in London could be due to the reduction of bus fares and improvements in the quality of bus services (Givoni, 2012), while in Gothenburg, it may be explained by the implementation of bus lanes, which reduced road capacity for car users (Börjesson and Kristoffersson, 2015). The results in Milan point to a more complicated process. The reduction of road traffic volumes was lower along routes with public transport, which could be because individuals living in those areas may also be public transport users (Gibson and Carnovale, 2015).

Schemes also differ in the use of revenues, which can be used to improve roads, public transport, and infrastructure to support active travel, or even to optimize freight distribution. In Bergen, where revenues were used to improve the road network, congestion increased (Lian, 2008). In other Norwegian cities and in Swedish cities, revenues from road use charging schemes were mostly used to improve public transport, and congestion decreased.

Charges can apply to specific trips, rather than to all trips. For example, in US cities such as New York, San Francisco, and Chicago, charges are added to ridesharing trip costs. Liang et al. (2022) showed that a congestion tax that surcharged trips that were not shared led to a shift from single-passenger to shared trips in the Chicago city centre. This did not reduce road congestion, given the small modal share of ride-hailing. In addition, users may simply switch to conventional taxis. The number of ride-hailing vehicles circulating may also not decrease, at least in the short term, as owners have already invested on them.

3.2. Fuel price

Policy measures affecting the price of fuel might contribute to mitigating congestion, but evidence is scarce. Khoo et al. (2012) and Burke et al. (2017) showed that reducing fuel subsidies in Malaysia and Indonesia, respectively, has reduced road traffic volumes, but the impact was small. Elasticity is widely used in economics to reflect the responsiveness of the quantity of demand to a change in one of its determinants. The elasticity of road travel demand to fuel price, measured by the percentage change in travel demand quantity to a percentage change in fuel price, was estimated as −0.16 (in Malaysia) and −0.2 (in Indonesia). However, studies have looked at short-term effects only. The long-term effect of fuel prices on traffic volumes is unclear.

3.3. Licence plate-based restrictions on vehicle use

Vehicle restrictions are legal bans on the use of some or all vehicles on some roads or at some days or times. Several cities in Asia and Latin America have banned the use of private cars on alternate days, based on licence plate numbers. As shown below, the results were not always as intended.

In Beijing, private cars are banned from one of the outer ring roads on weekdays from 7:00 to 20:00. The ban is based on the last digit of the licence plate. Each vehicle is banned one day a week. The restriction has been linked to an increase in road travel speeds, but to no significant impact on road air pollution, which suggests that traffic volumes may not have declined much (Sun et al., 2014). The study of Gu et al. (2017) found that the restriction reduced car trips and distance travelled by one-vehicle households, but this was accompanied by changes in travel patterns, with more travel on unrestricted days or using unrestricted vehicles. Wang et al. (2014) showed that compliance is also a major issue: 48% of car owners circumvented the restriction by buying additional vehicles, with different licence plate last digits, or simply by covering the plates or borrowing plates or cars from others.

A similar type of vehicle restriction measure was applied in Tianjin, with private cars not allowed to cross the city's outer ring road, from 7:00 to 19:00 on weekdays. The effects were not as expected: instead of decreasing, the proportion of car commuters increased, from 78% to 82%. In addition, 37% of public transport users switched to private cars on unrestricted days (Jia et al., 2017). The explanation is that initial reductions in travel speed encouraged some individuals to commute by car on unrestricted days.

In Shanghai, the restriction is not based on the last digit of the licence plate, but on car registration location: vehicles with non-local licences are banned from motorways in the central area in the morning and evening peak times. An analysis of the impact of an extension of these times showed that traffic volumes decreased and traffic speeds increased across the road network, but only within one month of the extension. There were no discernible effects after one year (Huang et al., 2022). This was because users adapted their behaviour, travelling on other routes or at different times.

The results were more encouraging in Zhengzhou, as suggested in the study of Zhao et al. (2019). The implementation of licence-plate restrictions based on digit numbers was associated with a decrease in the share of private cars from 68% to 28% and with an increase in the public transport share from 9% to 34%. However, the study did not assess the impact on traffic volumes or speeds.

In Delhi, sporadic restrictions have been applied, based on an odd/even formula: vehicles with odd/even licence plate numbers can only be used on odd/even dates between 8:00 and 20:00. There are no restrictions at other times. Women driving alone or with children are exempted. In 2016, this restriction reduced car traffic by 20%. However, this was accompanied by an increase in non-restricted vehicles (motorcycles, buses, and auto-rickshaws). The change in vehicle occupancy was insignificant. The expected increase in traffic speeds was only visible in the off-peak time on arterial roads away from shopping areas. In other times and areas, speeds increased little or even decreased (Mohan et al., 2017).

In Mexico City, cars are banned one day a week, during weekdays. The measure did not have the intended effects of reducing car use, as many households circumvented the ban by purchasing additional vehicles (Eskeland and Feyzioglu, 2007) or travelling more on unrestricted weekdays or weekends (Guerra and Millard-Ball, 2017). Gallego et al. (2013) showed that roadside pollution concentration in Mexico City has increased, which suggests that traffic volumes have also increased, despite the restriction. A similar result was found for a similar policy measure in Santiago de Chile.

3.4. *Low emission zones*

Cities such as London, Madrid, and Milan have implemented low emission zones, restricting the use of some types of vehicles (the most polluting ones) in a defined area. Bernardo et al. (2021) showed that these zones reduce emissions but not congestion. The initial reduction in traffic volumes results in faster speeds, which may induce new traffic. In addition, multiple-vehicle households may increase their use of less polluting vehicles. The unintended traffic diversion effects of cordon charging also seem to apply to low emission zones. For example, the low emission zone in Madrid reduced traffic volumes by 9% inside the zone but increased traffic volumes in other areas (Tassinari, 2022). Even inside the zone, traffic volumes returned to previous levels seven months later. This could be because households replaced older vehicles with new ones, which can enter the low emission zone.

3.5. *High-occupancy vehicle lanes*

High occupancy vehicle lanes (HOV) are road lanes banned for vehicles carrying less than a given number of passengers. Usually, the lanes can only be used by public transport vehicles or private vehicles with at least one or two passengers, besides the driver. In most cases, the ban applies only at peak times. The objective of this measure is to promote car-pooling and the use of public transport.

HOV lanes are common in US cities. For example, California has almost 1200 miles of HOVs. However, Kwon and Varaiya (2008) showed that, on average, these lanes provide little travel savings, compared with general lanes, their main benefit being more reliable travel times. The authors conclude that HOV lanes only reduce overall congestion slightly, and only when the general-purpose lanes are allowed to become congested.

Cohen et al. (2022) analysed in more detail the effect of the introduction of HOV lanes on carpooling behaviour, using data from a carpooling platform in Israel. The HOV lanes encouraged new users to join the platform and increased the number of car pool offers sent by drivers on the platform. However, carpooling only increased in some of the HOV lanes. Authors found that the design of the HOV lane scheme was determinant: lanes operating both in the morning and evening peak (in opposite directions) and open to vehicles with two passengers (rather than three) had higher increases in carpooling. HOV lanes may also have wider network impacts, increasing carpooling on roads that do not have HOV lanes.

In Jakarta, HOV lanes did contribute to reducing congestion, when they were operating. Using anonymized traffic speed data collected from smartphones, Hanna et al. (2017) found that the sudden cancellation of the HOV lane scheme on two major roads in 2016 led to considerable delays in the peak periods on those roads. In addition, delays propagated widely to other roads and at other times, even though the restriction never applied to those roads and times.

3.6. *Lottery of new vehicle licence plates*

Licence plate lotteries attempt to reduce car use through a reduction in car ownership. Beijing has implemented this measure in 2011. Only a limited number of vehicle licence plates are issued per month. These plates are allocated to applicants through a lottery. This has translated into a long time for applicants to obtain a licence, and thus purchase a vehicle, due to the large volume of applicants and the small number of lottery allocations per year. In 2015, the probability of winning the lottery was below 1%. The measure achieved its objectives. As shown by Yang et al. (2020), the city's fleet of private vehicles declined by 14%. In addition, households who owned old vehicles and did not win the licence plate lottery tended to drive less than those who won the lottery to purchase a new vehicle. The authors also estimated that cancelling the lottery scheme would lead to a 10–15% increase in vehicle miles travelled at peak times. Quan and Xie (2022) provided further evidence on the success of this measure in changing travel behaviour: the long wait for winning the licence plate lottery was associated with lower odds of driving for commuting after winning. This contributed to a reduction of 8.5 million km in the total vehicle-km driven in the city.

3.7. Parking policies

Policies such as parking restrictions and changes to parking pricing can be used as a strategy to reduce congestion. In Amsterdam, the increase in on-street parking prices reduced on-street parking volume (total number of hours vehicles were parked), which was not offset by an increase in off-street parking volume. In turn, this led to a 2–3% reduction in traffic flows in the city (Ostermeijer et al., 2022).

In San Francisco, the SFpark scheme introduced dynamic pricing as a means to optimize parking space. On-street parking charges vary according to the demand for parking at each moment. Millard-Ball et al. (2014) showed that this scheme led to a 50% reduction in cruising for parking, one of the main causes of congestion in busy city centre areas. Krishnamurthy and Ngo (2020) showed that this scheme also reduced road traffic volumes. However, this was mainly due to a reduction in lane occupancy (the average percentage of time a vehicle is detected in a given location) and not due to a reduction in vehicle counts (i.e. the total number of vehicles passing through that location).

3.8. Soft measures

Incentives have been used often as a strategy to encourage a modal shift from car to public transport, which can contribute to congestion mitigation. A series of studies report the case of an experiment that provided financial incentives for individuals to avoid travelling by car in peak periods along the Zoetermeer-The Hague corridor in the Netherlands (Ettema et al., 2010; Ben-Elia and Ettema, 2011; Kumar et al., 2016). All studies found a reduction in peak-time travel, but only while the scheme was active. After the scheme ended, travel patterns reverted to the original situation. Even while the scheme was active, the reduction of peak-time car travel was achieved mainly by shifting peak-time car trips to the times before and after the peak, not by shifting car trips to other modes (Ettema et al., 2010). In addition, avoidance of peak-time car travel was not influenced by the incentives but by several mediating factors, such as socio-demographic characteristics, worktime flexibility and scheduling constraints, habits, attitudes, access to information, and weather conditions (Ben-Elia and Ettema, 2011).

Müller-Eie et al. (2019) reported a personal travel planning initiative in Stavanger, Norway, including reduced public transport fares, free bicycle share trips, loans to purchase e-bikes, and travel advice. On average, this reduced car trips by 15% among participants. However, this reduction was driven by changes in behaviour of less than half (40%) of participants. The other 60% did not change their levels of car use.

An initiative to improve matching for carpooling in Wellington, New Zealand, led to an increase in carpooling from 12% to 27% and a decrease in the proportion of road users driving alone from 37% to 30% (Abrahamse and Keall, 2012).

Finally, Geng et al. (2020) reported a scheme in Hefei, China, involving the provision of information to travellers. Environmental information alone was not significant, but when combined with health information was associated with a shift from car to walking and cycling and a reduction of car travel. However, this behaviour disappeared after 1.5 years.

4. Synthesis

This paper used as a base the assumption that building new roads or upgrading existing ones can only reduce congestion in specific roads and only in the short term, not in the whole road network or in the long term. Previous theoretical and empirical work suggested that congestion can only decrease in the long term by improving public transport alternatives to car travel (Mogridge, 1990; Downs, 1962) or by measures to reduce car use, especially a combination of soft and hard measures (Cairns et al., 2008). This paper reviewed recent evidence, in order to confirm whether the assumptions above still hold, and to assess which policy measures are more effective in reducing congestion.

Our review confirms that investments in road building or upgrade do not reduce congestion. This is evident in the differences in the outcomes of road use charging schemes in Norwegian cities. In Oslo, the revenues of the scheme were invested in the public transport network, and congestion fell. In Bergen, the revenues were invested in new roads, and congestion increased. Our review also suggests that investments in the rail network reduce congestion, which could be a part of a package of measures also attempting to reduce car use. However, we did not find any study isolating the effect of specific types of investment (e.g. fare reduction, improved reliability, comfort, safety and personal security). We also did not find any study isolating the effect of improvements in pedestrian and cycling networks on road congestion.

We found that road use charging and rotating vehicle restrictions based on licence plate numbers can be counterproductive, when we consider long-term behaviours, as many road users will try to circumvent the charges or bans by travelling in uncharged or unrestricted roads or times. In the case of vehicle restrictions, they may even purchase an additional vehicle. Soft measures such as incentives and the provision of information have mostly short-term effects. Measures to curb vehicle ownership, such as the allocation of vehicle licence plates through a lottery in Beijing, tend to achieve more sustainable results. More evidence is needed on the congestion impact of measures affecting fuel prices, HOV lanes, and parking policies.

The following conclusions can be drawn regarding the three specific questions the paper set out to answer.

1. **What explains the success or failure of policy measures in reducing congestion?** Our review suggests that the success of these measures is dependent on the implementation of measures to improve public transport. Failure is explained by the inability of the

measures to account for road users' attempts to circumvent the measures, such as driving in uncharged or unrestricted roads or times, rotating the use of multiple vehicles, or purchasing new vehicles.

2 **Can the reduction of congestion be sustained in the long term?** Several of the reviewed measures reduced congestion in the short term but not in the long term. This could be because the factors explaining the reduction ceased to apply (the case of incentive-based schemes, for example), or because of a readjustment of travel behaviour. The initial improvement in road travel speeds can induce an increase in car use, from travellers who previously did not use cars because of congestion. This is an effect similar to road building, as identified by Cairns et al. (2008). However, the studies reviewed did not test for this effect. In some cases, policy measures can have a long-term effect on reducing congestion. Road use charging in London, Oslo, Stockholm and Singapore, where it was complemented with the improvement of public transport services, led to a long-term reduction in congestion. In addition, the removal of charging in an area of London where traffic had reduced by 5% did not result in a reversal of traffic volumes to their original volumes, which suggests that road use charging can lead to changes in travel behaviour even after the scheme ceases to apply.

3 **Are combinations of measures more effective in reducing congestion than single measures?** The combination of measures to reduce car use, such as road use charging, and improvements in public transport, tend to be more effective than the application of these measures separately. The experience in Singapore is particularly encouraging. A combination of measures to restrict car ownership and use, plus continued improvements in public transport have kept congestion at low levels, despite the increase in population and income and the land use constraints. The combination of car use restrictions and car ownership in Beijing has also proved to be effective.

Based on these results, our recommendation to policy-makers aiming at mitigating or eliminating congestion is to avoid further road building or major upgrades to existing roads to increase road capacity. We also recommend measures that have proved to be effective in reducing congestion, such as road use charging, especially in combination with improvements to public transport infrastructure and services. This can be complemented with soft measures such as the provision of information for users to make better travel choices, the provision of information, and support of incentive programmes implemented by employers.

CRediT authorship contribution statement

Paulo Anciaes: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Yan Cheng:** Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Stephen John Watkins:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

Financial statement

This study was supported by the Fundamental Research Funds for the Central Universities (No. 22120240058) granted by Tongji University, which funded the open access fees. The funder did not influence the research reported in this paper.

Declaration of competing interest

No conflicts of interest to declare.

Data availability

No data was used for the research described in the article.

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