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Suppressed traffic: A review of road capacity reduction policies and impacts

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Abstract

Transportation planners are familiar with the phenomenon of induced traffic when road capacity is improved through new supply or faster travel speeds. This paper reviews the evidence for an inverse effect, known as suppressed traffic. The effects of physical road capacity reductions, including infrastructure removal and reallocation of road space to other modes, are poorly understood. The paper begins with a typology of policy measures which reduce road capacity. Then theoretical frameworks which can be used to predict the impacts of suppressed traffic are reviewed. The literature review found two types of studies on this topic: studies gathering empirical evidence of suppressed traffic using cases from around the world, and studies investigating the distribution of benefits and disbenefits of road capacity reduction. Finally, implications of road capacity reductions for policy and planning practice are considered.

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Keywords: traffic suppression, infrastructure removal, road capacity reduction, road space reallocation, road pricing

1. Introduction

A publication by European Commission has proposed that road capacity should be reduced in city centers. Boldly titled, "Reclaiming City Streets for People: Chaos or Quality of Life?", the report begins with a vision of reducing urban road space for cars as populations grow:

> "Every year more than 3 million cars are added to the car fleet in Europe. Total road traffic kms in urban areas will grow by 40 % between 1995 and 2030. Local authorities and citizens need to decide how to respond to these pressures and decide what sort of place they want their town or city to be in the future…This new handbook sets out some case studies where road space has been reallocated for other uses. New, attractive and popular public areas can be created on sites that were once blocked by regular traffic jams." (European Commission, 2005)

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The report goes on to acknowledge that removing capacity from an already congested network is a controversial policy measure that defies conventional logic and negatively impacts drivers, a powerful political constituency. Yet in practice, it claims, cities that have implemented policies which deliberately frustrate car movement have not experienced traffic chaos, but a host of benefits that citizens love, while a portion of car traffic has simply disappeared, or 'evaporated.' This study asks whether this outcome may be too good to be true. Is the proposal to solve environmental and traffic congestion problems by reducing capacity for cars a feasible one? Does traffic disappear, or simply divert to other routes and times? To explore these questions, suppressed traffic is considered as the inverse case of induced traffic. Changes in road supply are the focus, rather than operational or policy measures, and evidence is gathered from empirical studies rather than modeled effects.

2. A typology of road capacity reduction measures

Road capacity may be understood as the maximum traffic flow obtainable on a given roadway using all available lanes, usually expressed in vehicles per hour or vehicles per day. A capacity reduction results when a physical, regulatory or operational change reduces the maximum traffic flow possible on the roadway from its original state. A selection of policy measures that reduce road capacity for cars is shown in Table 1.

Table 1. Selected policy measures that reduce road capacity for cars

Physical measures

	Examples	Description
Diversion of car traffic to protect central areas and neighborhoods	Traffic diversion	Through traffic restricted by constructing a physical barrier across the roadway
	Traffic cell	A system of one-way streets that to route traffic in and out of a central area and prevent through traffic
	Transit mall	Road restricted to transit vehicles and taxis, usually on a main shopping street
Downsizing roads to slow car traffic and encourage land use changes	Road diet	A lane of traffic removed (e.g. from two lanes to one),to reduce travel speeds and/or make room for a bicycle lane
	Viaduct replacement	Replacing an elevated road with a lower-capacity at-grade road (e.g. from a viaduct to a boulevard)
Reallocation of road space from cars to alternate modes of transportation	Pedestrian zone	Only pedestrian traffic permitted on roads within a central shopping area, often a main square and adjacent streets
	Bus lane	Lane restricted for use by transit vehicles, usually on major arterials
	HOV / toll /carpool lane	Lane restricted for use by vehicles with two or more passengers, usually during peak times on highways; some areas allow use of these lanes for a toll
	Bike lane	Dedicated space for bicycles, marked with paint and/or bollards, usually 4-5 ft (1.5 m) width; often require parking removal or narrower car traffic lanes
Removal of road space and land use change from transport to other uses	Roadway removal	Road or freeway demolished and land redeveloped for a non-transportation purpose (e.g. from a freeway to a park or housing development)

Regulatory and operational measures

Reduced travel speeds for cars	Speed limits	Low-speed zone in central cities and neighborhoods with high pedestrian volumes, e.g. 25 mph / 30 kph zones
	Traffic calming	Roadway design elements to slow cars, e.g. speed humps, chicanes, kerb extensions, etc.
	Traffic signal priority	Re-timing traffic signals to give more time to buses and pedestrians; cars wait longer

This paper is focused on policy measures that reduce road capacity by physical means, although impacts of regulatory and operational measures are also not well understood and deserve further study.

3. Theoretical frameworks for suppressed traffic

3.1 Suppressed traffic as the inverse of induced traffic

When road capacity is added, through a new road or lane, the new capacity attracts new trips onto the road network as people change their behavior: shifting routes and modes and making new trips. (TRB, 1995) When people who are already using the road network respond to the travel time savings of new road capacity by changing their route, shifting from another mode of transport to driving, or making their trip at a different time of day, these are redistributed trips. When people begin making new trips they were not making before, or trade-off time savings for longer trips in the same amount of time, these are generated trips. Such new trips that are unleashed by travel time savings are considered latent demand; this represents travel that presumably was of lower value and were therefore suppressed under the initial lower-capacity conditions. Collectively these trips are known as induced traffic.

Travel behavior is widely considered to be consistent with classic microeconomic theory, where demand for travel increases as costs fall, and decreases as costs rise. (Downs, 2004) Starting with Downs in 1962, microeconomic theory framework has been applied to define and understand induced traffic, that is, the phenomenon where traffic volumes increase on roadways with expanded capacity due to a lower cost of travel. (Downs, 1962) Downs noted that commuters seek to minimize travel times regardless of income or demographic factors, therefore new road capacity which lowers the cost of travel time will increase the quantity of travelers, up to the point of maximum capacity. Increased road supply is not itself a pre-cursor to induced traffic; travel time savings are what prompt behavioral changes. There are several excellent studies documenting empirical evidence of induced traffic; excellent summaries of the literature are provided by Litman or Zolnik. (Litman, 2018)(Zolnik, 2018)

The landmark British SACTRA study from 1994 remains the most comprehensive study of induced traffic, reviewing empirical evidence from hundreds of experiences in Britain. (SACTRA, 1994) It concluded that expanding road capacity to chase demand growth is very inefficient—an assessment of the economic costs and benefits showed the benefits of new trips made on new road capacity were outweighed by the costs of increased congestion. The study also found that models used to forecast traffic volumes on new road capacity were systematically 10-20% below the actual traffic recorded, due to overlooking induced traffic in their methodology.

Lee et. al. provides fine definitions of induced traffic and induced demand, distinguishing between them as short run and long run effects. (Lee et al., 1999) In the short run, demand is assumed to be fixed; in the long run (e.g. 10 years or more) there may be a shift in the demand curve due to population growth or land use change, which may be considered induced demand. Over the long run, increased road supply can stimulate car-oriented new development, leading to induced demand. Longer trips tend to get 'locked in' as drivers trade-off travel time savings for longer distance trips to residential, work and shopping destinations. Rising VMT erodes travel time savings in the short term (as new road space fills up), and leads to more road supply in the long term (as planners and politicians respond to public pressure for new roads). Empirical evidence for this dynamic was found in a study of California freeway expansions over the period 1979-1990; every 10% increase in lane miles was associated with 9% increase in vehicle miles travelled (VMT). (Hansen and Huang, 1997) The tendency of land use development to respond to travel time savings means that generative traffic effects tend to magnify over time, therefore long term elasticities are usually estimated as higher than short term. Estimates of the elasticity of induced traffic from adding road lane miles range from .24-.6 to in the short run and .64 to 1.0 in the long run. (Noland, 2001)(Cervero, 2003)(Goodwin, 1996)

Hills noted that when maximum capacity is exceeded, traffic congestion will begin to reduce road capacity and travel times and have a deterrent effect on travel: "To the extent that travel increases overall, it can be said to have been induced by the road improvement. Conversely, congestion as it spreads on the network will deter some travel and can be said to have a traffic suppression effect." (Hills, 1996) Congestion has the effect of increasing the cost of travel, through longer travel times, so economic theory predicts that fewer trips will be made.

Figure 1 illustrates this theory of suppressed traffic as the inverse of induced traffic. The axis labeled 'quantity of travel' represents the amount of traffic using the road, and the axis labeled 'generalized cost of travel' represents the cost of travel in both monetary and time cost. The line S1 represents supply of road capacity before any interventions. The line S2 represents supply of road supply after a capacity reduction due to a disaster, road works, or the policy measures listed in Table 1. The demand line remains fixed as no change in underlying demand for travel is assumed (e.g. from population change). Q1 shows the original traffic volume on the road, and Q2 shows the new traffic volume after the capacity reduction event. S2 has shifted inwards along to show that less road capacity is available relative to S1, and the change in supply has increased the cost of travel from P1 to P2. Traffic volumes have fallen by the amount Q2-Q1, which is the suppressed travel effect.

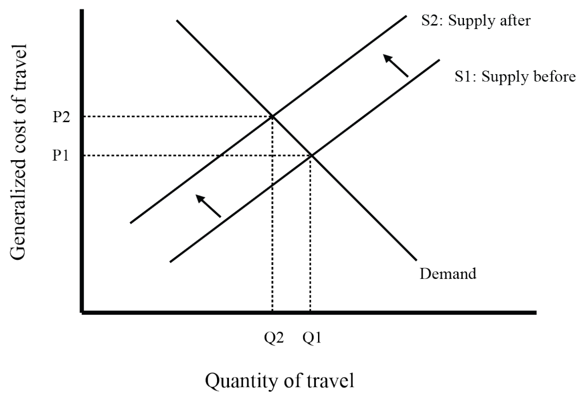

Figure 1. Suppressed traffic

Suppressed traffic is defined as the inverse of induced traffic: as road capacity is reduced, travel time costs go up (due to increased congestion or switching to a slower mode of travel), which leads to decreased demand for driving. The driving trips that never occur because of reduced road capacity are suppressed trips, (the corollary to generated trips). These unmade trips are also sometimes referred to as 'disappearing traffic' or 'traffic evaporation'. Economic theory says that drivers will only make these trips if the costs outweigh the benefits, that is, they cost less than P2. Suppressed traffic has mainly been considered as a short term effect, as it is difficult to estimate how an outward-shifting demand curve (with population growth) over the longer term affects latent demand. Presumably it would increase, as illustrated in Figure 1. When road capacity is reduced, the supply curve shifts inward from S2 to S1, while the demand curve still shifts outwards from D1 to D3 (mainly due to population growth). Thus the cost of travel increases from P3 to P1, and the amount Q2-Q1 represents the amount of travel suppressed by the road capacity reduction.

The corollary is for suppressed traffic in the long run is unclear, as potential land use changes are also suppressed. Behavioral research generally finds that people are more likely to shift into cars than out of them, so simply reversing the estimates of induced traffic will not produce the correct estimate of suppressed traffic. While microeconomic theory is useful to demonstrate that suppressed traffic exists, more information about driver behavior and local factors is needed to predict its magnitude.

3.2 Suppressed traffic as a consequence of shifting urban priorities

In the micro-economic theory, the key mechanism driving behavioral change for induced traffic is the benefit of increased travel speeds; benefits accrue to drivers who realize travel time savings. In the case of suppressed traffic, what are the benefits of reduced road capacity, and who do they accrue to? Travel times typically increase for drivers, so they experience a disbenefit. Perhaps pedestrian and bicyclists realize some travel time savings, but likely insufficient to outweigh the disbenefits to drivers. It is more likely that the benefits motivating road capacity reduction measures are not related to mobility at all; rather, travel time savings are being traded off for other social goods that are considered more valuable.

In their study of the politics behind freeway removal in the U.S., Napolitan and Zegras named a reduced value of mobility as a pre-cursor to road capacity reduction. (Napolitan and Zegras, 2008) They documented how decisions to remove freeways in San Francisco and Milwaukee were preceded by public struggles over the value of mobility versus other values such as neighborhood quality of life, economic development, and urban revitalization. In both cases, a group of 'winners' (neighborhood residents and development interests), faced off against a group of 'losers' (residents of other neighborhoods and suburban commuters) in public debates over whether to preserve the travel time savings offered by aging freeways, or whether to replace them with surface boulevards with slower speeds but more neighborhood-friendly land uses. In both cases, interests in favor of reduced mobility ultimately prevailed, representing a shift in urban priorities. Yet the researchers noted that this outcome was also dependent on the 'other-than-mobility' values being embedded in power, that is, the freeway removals succeeded because these values were held by those in power (whether collectively by a group or by an individual such as the Mayor).

There is evidence to support this theory in the case reports by European cities where road capacity reductions have been implemented. (European Commission, 2005) City planners in charge of the projects reported that before traffic restraint measures could be implemented, public discussions weighing motor vehicle mobility relative to other factors took place. They emphasized the need to pair road capacity reduction measures with improved transit services and measures that improved conditions for walking and bicycling, like streetscape improvements and the provision of shared bikes. Plans only moved forward if city officials were willing to deprioritize vehicle mobility in favor of benefits referred to collectively as quality of life, such as : travel time savings for buses, bicyclists and pedestrians, and a host of qualitative benefits such as improved mobility and safety for pedestrians and bicyclists, reduced air pollution and noise, and increased public satisfaction ratings. Before and after public opinion polls, rather than traffic counts, were often used as the measure of success for interventions like creating a central pedestrian zone or closing a main street to car traffic.

In this theory of suppressed traffic, behavioral changes are motivated by the benefits of road capacity reduction which accrue to non-drivers: higher quality of life. Planned road capacity reductions are most often accompanied by increased supply for alternative modes of travel. Paired measures aim to both increase transport capacity for non-drivers (i.e. transit, bicycles, etc), and improve quality of place through land use changes. While car trips may be suppressed, they may be replaced by ne w trips using other modes to enjoy the impacted area,"as 'exchange space' rather than just 'movement space.'" (European Commission, 2005) Perhaps the most famous success story along these lines is the removal of the Cheong Gye Cheon elevated freeway in Seoul, Korea, which was torn down in 2003 and replaced by an urban stream and linear park in the city center. (Kang and Cervero, 2009)

4. Literature review

This study found two bodies of literature on the topic of suppressed traffic: studies presenting empirical evidence, and studies considering the distribution of benefits and disbenefits. These are discussed in turn.

4.1 Empirical evidence of suppressed traffic

Interest in suppressed traffic was sparked by the UK's SACTRA study, which concluded that induced traffic was a real and measurable phenomenon. (SACTRA, 1994) Studies documenting impacts of road capacity reductions are generally of two types: cases where traffic counts had been done before and after a planned policy intervention, and cases where cities had to cope with the sudden loss of road capacity due to an engineering or natural disaster.

Driver responses to road capacity reductions are generally assumed to be a mild inverse of the triple convergence effect: changes in route choice, time of travel, and mode of transport. However a review of observed experiences revealed that people's responses to road capacity reductions are actually more complex than generally assumed by practitioners or allowed for in traffic demand models.

A major study on suppressed traffic commissioned by London Transport is the definitive study on suppressed traffic to date. (Cairns et al., 1998) The final report provided a conclusive review of more than 60 cases of road capacity reduction gathered worldwide. It included three types of road capacity reduction experiences: changes in road allocation due to implementation of bus lanes or pedestrian zones; capacity reductions as a side-effect of maintenance or structural repairs; and capacity reductions resulting from the loss of infrastructure in natural disasters such as earthquakes. Although clearly this represents a range of planned and unplanned road capacity reductions, the range of behavioral responses available to drivers was considered similar. Its key findings were a) when roadspace for cars is reallocated, b) local traffic problems are low magnitude and short term; c) overall traffic levels can drop by a significant amount; and people react in more complex ways than traditionally assumed. It concluded that the overall reduction in traffic, accounting for spillovers on parallel routes, averaged 25% from original traffic volumes. They refined this finding by excluding nine exceptional cases and found that over half of the remaining cases had observed overall traffic reductions of more than 16%. The report was conflicted as to the practicality of a general approach to modeling traffic reduction effects.

A follow-on version of the study included twelve more case studies and responded to criticisms of the original study. (Cairns et al., 2002) This study included the findings from a conference on suppressed traffic and a survey of transport professionals, bolstering the conclusion that evidence for suppressed traffic is robust. The percentage change in traffic levels after road capacity reductions occurred ranged from an increase of 26% to a decrease of -147%. Among all the cases, the average traffic reduction was --22%, and the median was -11%.

The authors cautioned that "It would be wrong to use as a universal rule of thumb a presumption that [any standard percentage] of traffic will conveniently disappear as a matter of course whenever road space is reallocated. It would also be wrong to assume that no traffic will disappear…the effects of a particular capacity reduction will be substantially influenced by the circumstances of the case." (Cairns et al., 1998) They defined three broad network capacity situations which influence driver responses and resulting traffic flows, as shown in Table 2:

Table 2. Network capacity situations resulting from road capacity reductions and driver responses (Cairns et al., 1998)

Reduced road capacity	Driver responses
Reduced capacity is offset or more than offset by capacity increases on parallel routes or by traffic management changes.	Little or no change in driver choices, congestion, or overall traffic levels results – there is no real reduction in effective road capacity, and overall traffic volumes may increase.
Effective capacity is reduced on the treated route, but there is enough spare capacity on alternative routes or at other times of day, and no measures to discourage using them.	Traffic is reduced in the treated area, but redistributed to other place and times in the network. Congestion is spread out, but no net reductions in number of trips or vehicle miles travelled are achieved.
Road capacity is significantly reduced, and there is not adequate spare capacity on alternate routes or at peak times, due to either the nature of the network, the original level of congestion, or other measures included in the scheme design.	Trips spread out over time and space, and a portion of trips disappear from the road network. A net reduction in amount of driving is achieved, as drivers change trip frequency, distance and mode of travel.

In the third set of cases where traffic was suppressed, the authors concluded that traffic disappears, "only to the extent that it needs to do so...This occurs due to responses by a proportion of drivers who take action to avoid what they consider, in relation to their prevailing experience, to be unacceptable conditions." (Cairns et al., 1998) A wide range of responses by drivers was observed, depending upon factors such as income level, trip purpose, and the availability of alternate modes of travel. The study concluded drivers' responses to road capacity reductions is ultimately determined by:

- The nature of the network and existing levels of congestion
- The type of trip affected
- The relative attractiveness of alternative locations
- Other factors influencing car use, particularly parking controls
- The real or perceived attractiveness and availability of other modes
- The specific design details of the scheme
- Information and marketing

In the first few days, initial cramming of the roads was followed by searching for alternative routes and times to travel. In the next months, drivers adjusted with more varied and flexible trip planning, changing modes, and reviewing the need to travel. In the longer term, they were switching activity locations or even home or workplace. The complexity of responses was attributed in part to the fact that many of these changes are being made under normal circumstances anyway, as a significant portion of people within a year change their income, job or home location, car ownership level or household structure, and accordingly their travel patterns. Cairns 1998 found from surveys of number plates that from 30% to 80% of the 'after' traffic is different individuals than were observed in the 'before' traffic. They described two basic sets of circumstances behind driver behavioral responses: one group of stable individuals whose responses are constrained by set habits and preferences, who resist changes other than minor route and time of day adjustments; and another set of individuals entering the traffic situation anew, who are more flexible and adapt rapidly to new network conditions. The balance of these two groups depends upon underlying demographic and socioeconomic trends, and helps explain the difference between short and long run responses. The authors concluded, "Individually or in combination these diverse driver responses to congestion can result in a proportion of traffic 'evaporating.'" (Cairns et al., 1998)

4.2 Distribution of benefits and disbenefits of traffic suppression

With evidence that suppressed traffic is a real phenomenon, and evidence that some drivers respond by eliminating some trips, the question must be raised of whether this is a good thing. Presumably the trips that drivers value the least are the ones that disappear. Benefits will be enjoyed by people whose circumstances are improved due to better public transportation services, less pollution and noise, and improved conditions for bicycling and walking (all depending upon the design of the particular scheme). Disbenefits will be suffered by people whose travel opportunities or conditions are worsened by the road capacity reduction, due to changing to a less preferable route, time, or mode of travel, or eliminating some trips.

Cairns et al. considered the benefits and disbenefits of suppressed traffic following the reasoning and conclusion of the SACTRA study, where the travel benefits realized by drivers using new road capacity were found to be outweighed by the disbenefits to the wider community. The inverse is that the disbenefits suffered by drivers from not using removed road capacity are outweighed by the benefits to the wider community. In other words, the group experiencing the greatest disbenefits, drivers accustomed to using the removed road capacity, is likely to be fewer people than are impacted by the benefits of reallocating the roadspace to buses, bicycles, and/or pedestrians.

The question still remains, what is the baseline level of latent demand for travel that exists in general, regardless of road supply? Since car ownership, car trips and car mileage are all generally increasing over time, that implies that road capacity reductions will result in disbenefits more widely than these studies acknowledge. Is latent demand for high value trips being suppressed, via road capacity reductions? Latent demand it is a difficult topic to study, as it depends upon documentation of the intention to travel, rather than travel itself. Disbenefits are difficult to quantify, as they can range from actual limitations of mobility (due to lack of a car or public transit service) to the perception by users whose travel preferences are unmet, (due to road or parking restrictions). While a 'zero mobility' situation can be understood (such as a prisoner in jail, or a person with severe disabilities), a 'perfect mobility' situation is more difficult to understand. There isn't a consensus on what comprises completely unlimited mobility, and therefore it is more difficult to establish what is an acceptable level based on trade-offs between personal and social welfare. Road supply decisions by policy makers help shape the real-world constraints that force trade-offs by individuals who desire certain activity and travel patterns.

A recent study sought to measure and estimate suppressed travel as an indication of latent demand for travel by considering demand for transportation as derived from an activity agenda which is executed throughout the day. (Bellemans et al., 2009) An enhanced travel diary was used to capture planned travel as well as executed travel as a way to record suppressed travel and estimate latent demand. Participants kept their activity-travel diary using software which linked planned, executed and cancelled travel episodes. They reported their travel plans for the next day each evening, and logged executed trips at the same time. This allowed the researchers to identify characteristics and circumstances of trips which were planned but not executed. They found that approximately one-third of planned trips were suppressed, and of those, 12% resulted in the planned activity being achieved through trip chaining. The remainder of suppressed travel was due cancellation of the planned activity altogether. Trip purpose was logged, revealing which trips were the most likely to get cancelled: leisure and touring, education, and eating out.

4. Implications for policy and practice

The European Commission Directorate-General for the Environment commissioned a report on the potential benefits and co-benefits of traffic reduction schemes to promote them as a model policy for European cities. (European Commission, 2005) The report cites widespread public support for such measures as one reason many cities are pursuing traffic suppression as an explicit goal. Figure 2 shows responses to a question in the Eurobarometer survey of 1999, “In your opinion, which one of these would make it possible to most effectively solve environmental problems linked to the traffic in town?”

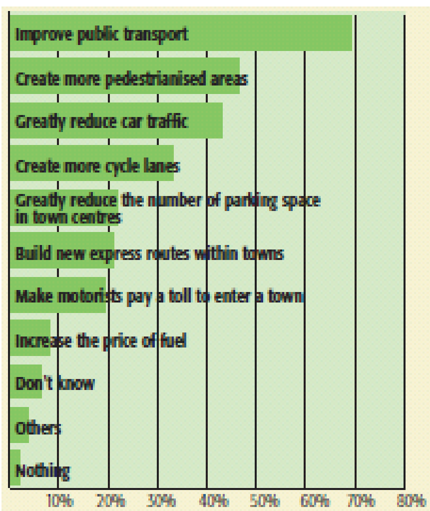

Figure 2. Public support for traffic suppression measures (European Commission, 2005)

The report explores the motivations for and results of road capacity reduction schemes by considering eight case studies, mainly traffic closures to create pedestrian zones in medieval city centers, in England, France, Germany, Belgium and Finland. Motivations for the schemes were described as efforts to improve environmental sustainability, to improve social equity, and to de-couple economic and traffic growth. Goals included creating opportunities for urban revitalization, reducing air pollution and noise in city centers, and creating road space for public transportation, bicycling and walking.

The findings of the report were consistent with (and in part based upon) the landmark Cairns 1998 study, stating, “in the majority of road reallocation case studies, a significant reduction in traffic was observed, despite a broader context of rising levels of car ownership and general increasing levels of traffic in urban areas.” (European Commission, 2005) However a number of caveats to the findings presented in the report were given:

- Random variations due to variability in daily traffic are not reflected in the traffic counts
- Traffic counts likely do not fully account for longer distance detours made by drivers avoiding the road measures which outside the traffic measurement zone
- Screenlines measuring passing vehicles do not count shorter distance traffic diversion within the measured area, changes in the number of trips, or trip mode
- Traffic growth which occurs due to non-road measure factors such as underlying demographic and land use changes, and increases in income and car ownership, cannot be isolated from the actual impact of road

capacity reduction schemes, which "may lead to a significant underestimation of the positive effects of road capacity reduction"

A survey of transportation professionals conducted asked practitioners worldwide whether they thought reduction of road capacity should be an explicit transport policy goal. (Cairns et al., 2002) Over two-thirds of the 200 respondents thought that it should. Respondents commented that traffic reduction was an underlying prerequisite to achieve desirable levels of congestion and pollution, which measures such as clean vehicles and traffic management could not achieve alone. They also commented that even if all vehicles were clean and free flowing, high traffic volumes in residential areas creates severance issues, limits the mobility of vulnerable groups such as children and the elderly, and may make the area unattractive to investors.

Road capacity reduction measures, such as those presented in the European Commission's case studies may also be appealing to policy makers for the multiple benefits they provide. It is appealing to think of unwanted traffic evaporating as people switch to more environmentally-friendly modes of transport. Yet it is clear that latent demand remains a little-understood topic, and likewise the ultimate long-term effects of traffic suppression. It is presumed by researchers that road capacity reductions would have the opposite long-term effects as induced traffic, yet evidence for this remains to be seen. Such an outcome would depend upon land uses in urbanized areas allowing for greater densities and affordability. It also depends upon coordinated land use policies that discourage land development that will force road capacity increases in the long run. It is a topic that deserves further study.

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