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**DOES ROAD TRAFFIC CONGESTION DRIVE PUBLIC TRANSPORT USAGE – AND HOW SHOULD WE RESPOND WHEN MAJOR PROJECTS SHIFT THE BALANCE?**

This paper examines the realities of road traffic congestion, and the mode shift between motor vehicle and public transport as a result of congestion. It considers the influencers of change and their on-the-ground effects, and explores the options for response to major projects that shift the congestion balance away from existing equilibrium levels.

The paper finds, from the limited available evidence, that there is a link between road traffic congestion and public transport patronage demand. It suggests that road improvement projects that improve road travel times are likely to reduce the comparative attractiveness of parallel public transport modes unless equivalent improvements to public transport travel times and reliability are also made.

# 1. Introduction

This paper examines the relationship between road traffic congestion and public transport, and specifically, at the role of congestion as a driver of public transport patronage and the public transport impact of major projects that alleviate (or exacerbate) road congestion levels. The paper aims to scratch the surface of the topic, and prompt further research and discussion, rather than provide the ‘solution to end all solutions’.

Somewhat surprisingly, the impact of congestion on public transport is not as well understood as might be expected, since most focus of research and commentary relates to the flipside relationship – the benefit of using public transport to address road congestion. The evidence of that relationship is often presented in a partisan way, as road and public transport advocates compete to prove that their option is the best use of the investment dollar. The complex relationship between transport and land use, and the dynamic nature of cities, makes this ‘which is best’ argument difficult to prove either way.

In any event, major congestion-reduction projects are common. They are often driven by strategic and/or political considerations, and implemented regardless of whether they are the best use of the investment dollar or are likely to deliver the best long term outcomes for the city, state, or country in question. So transport planners need to understand the likely short and long term impacts of such a project on other modes, and identify an appropriate response that makes best use of the changing operating environment.

# 2. What is road traffic congestion?

We are all familiar with road traffic congestion, but what actually is it? As OECD & ECMT (2007) note, there is no single broadly accepted definition of congestion, as it is both a physical phenomenon, where vehicles impede each other as road system approaches capacity, and a relative phenomenon, which is linked to user expectations with regards to road system performance.

Congestion isn't necessarily a bad thing, since it can be the consequence of urban and economic growth, reflecting our desire to live and work in close proximity in successful urban communities. It also plays an essential role as a balancing mechanism for coping with excess demand for limited road space (Downs, 2004). Nevertheless, road traffic congestion is generally viewed negatively, particularly when it is regarded as being excessive. OECD & ECMT (2007) define that as occurring when the marginal costs of the congestion to society exceed the marginal costs of efforts to reduce that congestion.

Congestion is generally expressed as the delay relating to the difference between actual travel time and travel time under uncongested or other acceptable conditions. Lomax, Turner & Shunk (1997) describe it as having four components that interact and vary between and within urban areas:

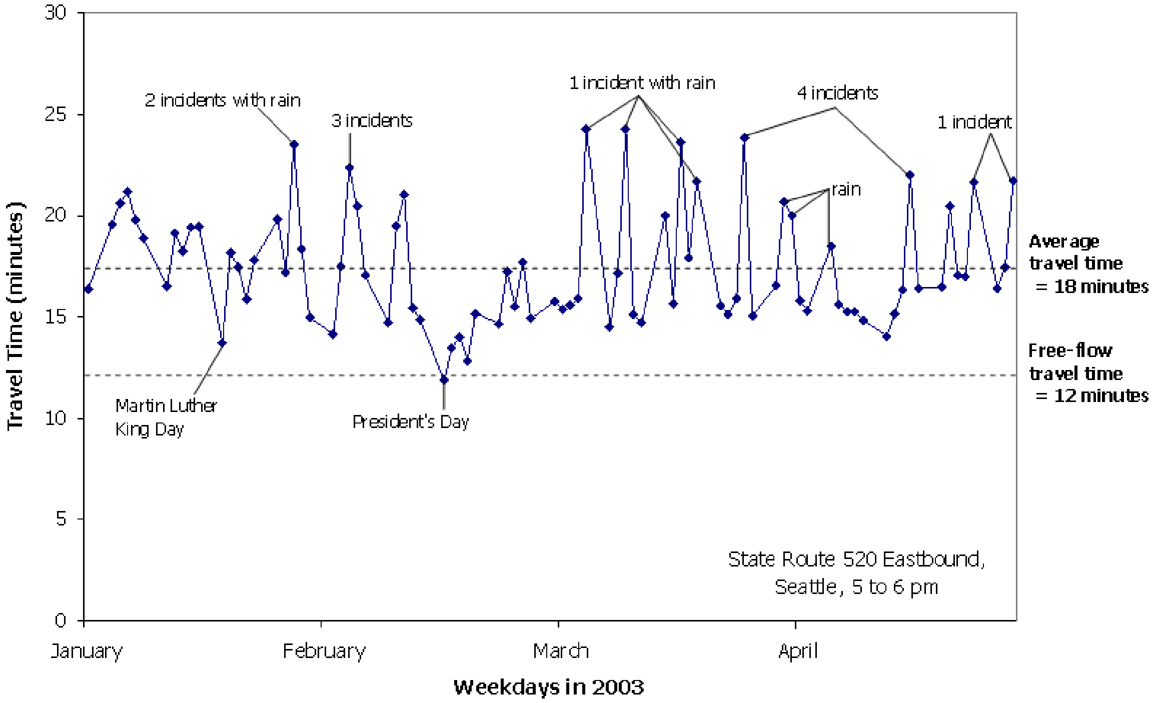
- **Duration**. The amount of time that congestion affects the road system.
- **Extent**. The number of people or vehicles affected and the geographic distribution of the congestion.
- **Intensity**. The severity of the delay.
- **Reliability**. The variation in the other three elements.

OECD & ECMT (2007) point out that the last of these may be of greatest concern to road users. Lomax et al (1997) agree that reliability is a key element, and note that it is particularly linked to non-recurrent congestion (due to accidents, vehicle breakdown, road works, special events, weather etc), which causes much greater delay variation and is much less easily predicted than recurrent congestion, which is generally linked to regular fluctuations in traffic volume and is somewhat stable and predictable.

While recurrent congestion is relatively stable and predictable, following the regular fluctuations of traffic volumes by the time of day and day of the week, it does change over time as urban areas grow and their transport links evolve. Recurrent congestion can cause particular reliability issues when roads near or reach their maximum capacity. In these circumstances, OECD & ECMT (2007) advise that, small changes in available capacity (due to such factors as differential vehicle speeds, lane changes, and acceleration and deceleration cycles) can trigger a sudden switch from flowing to stop-and-go traffic. Similarly, heavily congested intersections can quickly cause queues that have corresponding upstream effects. Surges in traffic, relating to seasonal or other major changes in travel patterns (e.g. 'Mad March') can also have a similar effect to non-recurrent congestion in these circumstances.

Figure 1 illustrates how peak period travel times vary in practice, showing both their relationship to non-recurrent events and to uncongested travel time on a major commuter route in Seattle, USA.

**Figure 1:** Example of the variation in actual travel times and their relationship to non-recurrent events and uncongested travel time (Source: Cambridge Systematics, 2005)




# 3. What are its behavioural effects?

As road traffic congestion-related travel time increases, the generalised cost of travel to the road-user also increases, and individuals start to look at other options. The potential responses vary widely. Some are actionable immediately and show up as the short run elasticity response, while others take longer to action and show up in the long run elasticity response. Booz Allen Hamilton (2006) suggests that these travel time elasticities are quite low in the typical Australasian city, at around -0.2 to -0.3 in the short run, -0.3 to -0.45 in the long run.

Salomon & Mokhtarian (as cited in Bovy & Salomon, 1999) identify the following types of commuting-related behavioural responses to congestion:

- **Accept travel costs**. Where individuals do nothing in response to the increased travel time and cost associated with congestion. Bovy & Salomon note that this is the most common response, and conclude that this may imply that congestion may not be as severe a problem as is generally believed.

- **Reduce travel costs**. Another 'do-nothing' response, where changes to the generalised cost of some travel aspects counter the increased generalised travel time cost, making individuals more accepting of congestion. Bovy & Salomon suggest that this tends to relate to ongoing technological advances that improve the in-car environment (e.g. air-conditioning) or make it more productive (e.g. mobile data).

- **Adapt departure time**. Where individuals adjust their departure time earlier or later to avoid the worst congestion. External constraints such as work schedules limit the viability of this option for many individuals. Over time, this response can lead to peak spreading, where roads are congested for a longer duration than previously, reflecting a broader peak period traffic flow profile.

- **Change to an alternate route**. Where individuals change to a less congested route if that is a viable option. This response may reduce commuting stress even though the new route may be longer or slower, but can spread congestion to new areas over time.

- **Buy time**. Where individuals are able and prepared to pay extra to travel via a faster tolled route, or pay for parking that is nearer to their destination, to avoid congestion or compensate for its effects. Increased travel time can also be compensated by buying time elsewhere in life (e.g. employing home help).

- **Change time**. Where individuals make use of alternatives such as flexitime, compressed work week and part-time hours to completely change their travel to avoid peak periods when congestion is worst. External constraints may limit the viability of this option for many individuals. This response can lead to peak spreading over time, similarly to adapted departure time.

- **Change mode**. Where individuals respond to congestion by switching to other modes, such as walking, cycling, and public transport, to avoid the congestion or make better use of their time when caught in it. The viability of the public transport response is influenced by the degree to which the public transport option (e.g. trains, ferry, LRT/tram, bus) is competitive in travel time and cost with the car option.

- **Telework (telecommute)**. Where individuals work from home or a different location to avoid travel on congested roads.

- **Relocate workplace or home**. Where individuals avoid congestion by making locational adjustments. This response can spread congestion to new areas over time.

- **Start a home-based business**. Where individuals avoid travel on congested roads by working from home, similarly to the telework option.

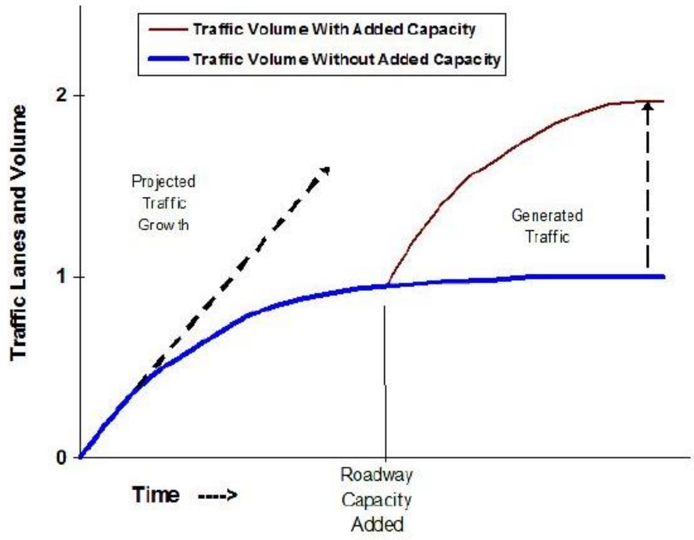
- **Stop working**. Where individuals have the option of not having to work, they may choose not to, solely to avoid congestion.

The above responses can be categorised into three broad strategies: responses that maintain the current level of travel (including those with variations to time, route or mode), responses that reduce travel, and life-style/locational changes.

As individuals respond to travel time increases by changing their travel habits (time, route, mode, amount of travel, or life-style/location) they release capacity at that time and/or location to others, and if they switch to another time/route, reduce capacity there. Other individuals then respond to the resulting change in travel time, by changing their own travel habits. This situation continues until the available capacity is filled and delays discourage additional peak-period trips, and a rough equilibrium is reached. The level of equilibrium will change over time, but is constantly self-adjusting in a process that Downs (2004) calls the Principle of Triple Convergence.

The self-adjusting equilibrium mechanism also applies when new infrastructure increases overall capacity. In that situation, Litman (2016) observes that expanded capacity will tend to fill with generated traffic, some of which will be induced (absolute increases in vehicle distance travelled), and some of which will be diverted (OECD & ECMT, 2007). Figure 2 illustrates this effect.

**Figure 2:** Generated traffic (Source: Litman, 2016)




This situation is described as the Fundamental Law of Road Congestion by Duranton & Turner (2011), based on earlier work by Downs in 1962, who find evidence that metropolitan vehicle-kilometres in the United States increase in exact proportion to metropolitan freeway lane kilometres, and suggestive evidence that this relationship may extend to a broad class of major urban roads. On that basis, they suggest that increased freeway capacity and major urban road capacity is unlikely to relieve congestion on those roads.

A wider literature review of induced travel by Currie & Delbosc (2010) finds more variability in long run lane kilometre elasticities, with a range between 0.29 and 1.1 and an average value of 0.69, from 13 studies. Three of the source studies report long run elasticities of around 1.0, and support Duranton & Turner's proposition that all increased capacity will filled by induced (and diverted) demand, but the others suggest that effect is lower, albeit very significant at the 0.69 average.

# 4. What does this mean for public transport?

Public transport patronage demand is driven by a wide range of factors, which are continuously at play and often in contradiction with each other, making it difficult to identify the effect of any one at any point of time. Streeting & Barlow (2007) state that these factors include:

- Endogenous (i.e. internal) factors such as:
  - Fare and service levels;
  - Service quality; and
  - Marketing and communications.

- Exogenous (i.e. external) factors such as:
  - Employment;
  - Income;
  - Tourism;

- Population;
- Fuel prices;
- Car ownership;
- Interest rates;
- Special events (i.e. where public transport use is mandated);
- Parking availability and cost; and
- Road traffic congestion.

So road traffic congestion is only one of many factors that influence public transport patronage. Unfortunately, while many of the other factors have been investigated in detail and their influence is fairly well understood, the effect of congestion as a public transport demand driver, and the particular impact of major road improvement projects on public transport patronage, have not been investigated to the same extent.

The cross-modal effect can be described in terms of the cross-elasticity[1] and diversion rate[2] with respect to changes in car in-vehicle travel time, which provide an indication of the sensitivity of public transport patronage demand to changes in car travel time. The international research into this relationship is limited, but Wallis (2004) draws conclusions from the evidence available at that time, and indicates that an average diversion rate of around 20% is appropriate for urban areas in Australasia. This implies an equivalent cross elasticity of 0.24, which is supported by the available evidence.

Intuitively, road traffic congestion will affect public transport modes that utilise a segregated right of way (i.e. train, ferry, and LRT/tram and bus with access to a separate corridor and/or high levels of on-street priority) differently from on-street public transport modes (i.e. LRT/tram and bus without priority). Increased road traffic congestion is likely to increase the comparative attractiveness of public transport modes that utilise a segregated right of way, by making their travel time more competitive, and offering better reliability than driving where the road alternative is at or near maximum capacity. On the other hand, increased road traffic congestion will directly affect the travel time and reliability of on-street public transport modes using the same corridor, and may make them less attractive than driving. So the effect of road traffic congestion on public transport patronage is likely to be different, depending on the degree of priority of the public transport mode.

The same affect can be expected to apply in reverse. Major road improvement projects that reduce road traffic congestion on a corridor can be expected to reduce the comparative attractiveness of parallel public transport modes that utilise a segregated right of way, and therefore their patronage, by reducing car in-vehicle travel time and improving the reliability of the road alternative in the short to medium term. This affect may be mitigated somewhat if equivalent travel time and reliability improvements are made to the public transport mode alongside the road improvements, to ensure that it remains competitive in these respects.

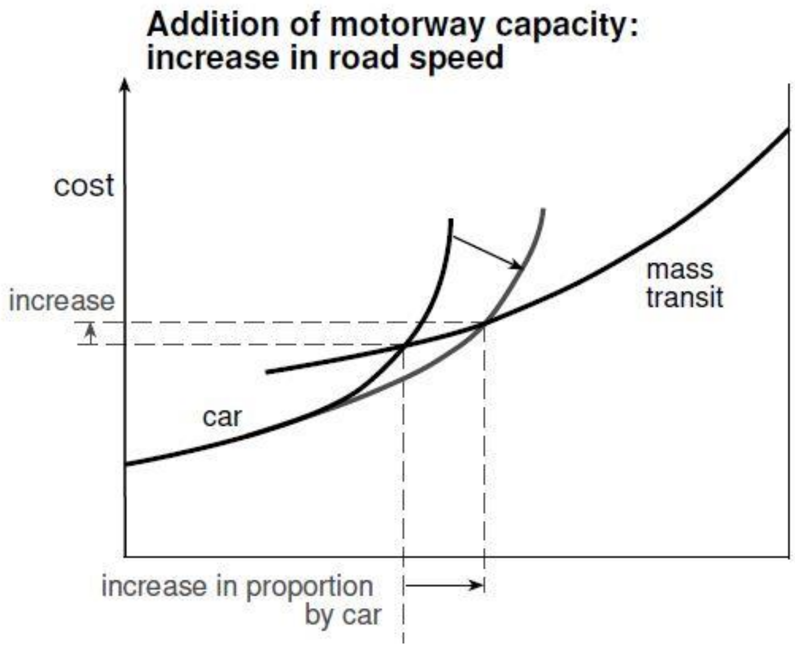
The effect of major road improvement projects that reduce road traffic congestion on a corridor can again be expected to differ for on-street public transport modes. There, the reduced road traffic congestion is likely to improve public transport travel time and reliability and make the public transport more attractive to passengers than previously. However, the degree of comparative attractiveness of the public transport alternative will again depend on the extent to which its travel time and reliability are competitive with the car alternative.

[1] The cross-elasticity is the proportionate change in public transport use relative to the proportionate change in car in-vehicle time.

[2] The diversion rate is the product of the elasticity of car demand with respect to travel time and the proportion of change in car demand that switches to public transport.

The impact of major road improvement projects on public transport modes can be explained by what is known as the Mogridge conjecture. As cited by Zeibots & Petocz in 2005, this suggests that an equilibrium mechanism exists between travel by car and travel by public transport in congested urban areas, similarly to the road equilibrium mechanism described above. In this case, when new capacity is added on a congested road corridor, some passengers on parallel public transport switch modes until or travel time on the road corridor increases to the point where both modes are at equilibrium and no further travel time advantage can be found. Mogridge suggests that final outcome can be a higher point of equilibrium, referred to as the Downs-Thomson paradox, where the marginal cost of trips is higher than prior to the increase in road capacity. This is relationship and outcome is illustrated in Figure 3.

**Figure 3:** The Downs-Thomson Paradox: Comparing Marginal Cost Outcomes of Adding Road Capacity (Source: Mogridge (1997) as cited in Zeibots & Petocz (2005))




Zeibots & Petocz (2005) have investigated the relationship between M4 motorway capacity increases and patronage on the Western Sydney and Richmond rail lines in Sydney (NSW), finding a statistically significant decline in passenger journeys on both lines when new road capacity was added. They conclude that the decline is evidence of mode shifting from the rail to road, and consistent with the Mogridge conjecture. Wallis, Wignall & Parker (2012) suggest that public transport mode shift may account for up to/about half of total induced traffic from this road project (c.7% across screenline), although they note that this result is not statistically robust.

Mewton, as cited by Zeibots (2007), has undertaken similar analyses of the Sydney Harbour Tunnel and Gore Hill Freeway in Sydney (NSW), finding statistically significant differences between before and after traffic counts and suggested mode-shifting from parallel train (and ferry) services after the opening of the Sydney Harbour Tunnel. No significant bus patronage change was found, a result that may be explained by the addition of a bus lane to the Sydney Harbour Bridge in line with the project. Wallis at al. (2012) suggest that public transport mode shift (principally from train) accounts for the majority of induced traffic from this road project (c.3% across screenline).

Wallis et al. (2012) provide some additional (albeit fairly old) evidence of the impact of major road improvement projects on public transport from four international projects. They note that the first, the completion of an orbital motorway in Amsterdam (Netherlands) resulted in minimal shift from public transport, although they suggest public transport is not a strong competitor in the dispersed origins/destinations served by the road. In the case of the Rochester Way relief road (London, UK), which provided a bypass on a major trunk route, public transport mode shift from train was estimated to account for 3% of 'after' trips and a significant proportion of overall induced traffic. In the case of the Newlands interchange (Wellington, New Zealand), which provided a grade separation at a major bottleneck, public transport mode shift (from train) accounted for 2% of 'after' trips. Finally, in the case of the London Hammersmith Bridge closure (London, UK), a capacity reduction rather than capacity increase scheme, 16% of former car users switched to public transport (which could still use the bridge) rather than travel by car via a longer route with a longer travel time.

While noting caution on the size of the above evidence base, Wallis et al. (2012) conclude that, for main radial corridors in large cities, where rail-based public transport services account for a substantial proportion of overall modal share, road improvement projects may induce mode shifts from public transport to car that account for up to half or more of the total corridor induced traffic, and an overall increase in corridor traffic of up to 2% to 3%. They note that: their conclusions relate principally to short term effects (within a few months of road opening) and that the extent of mode switching may be greater in the longer term; the mode shift is primarily from train rather than bus, reflecting that it was usually the dominant public transport mode in the corridors examined and generally a larger proportion of train users had cars available; and they expect that most of the mode shift effect to relate to peak periods when 'choice' travellers may have chosen train to avoid road traffic congestion, suggesting that the potential increase in corridor traffic of 2%–3% suggested above would represent a greater proportion of peak corridor traffic volumes.

# 5. How should we respond when major projects shift the balance?

So, a major road improvement project is about to proceed on a local corridor. It may be justified as the completion of a strategic link, to relieve excessive congestion, which may be due to capacity constraints or the lack of a strategic link, to provide (in whole or in part) public transport benefits by removing a bottleneck on a major public transport corridor, or by something else. What is the likely impact and how should we respond?

The response will obviously depend on the individual situation. However, we can assume that such a project will add capacity as most road improvement projects do, whether they take the form of a direct capacity enhancement or some form of bypass of existing roads and or intersections. This will improve car in-vehicle travel time, since there is little reason to invest in such projects if they don't offer travel time improvements, and the travel time improvements are likely to generate most of the benefits.

The evidence is limited, but if there is no equivalent improvement to public transport travel times and reliability, the improved road travel times can be expected to reduce the comparative attractiveness of parallel public transport modes that utilise a segregated right of way, and therefore significantly impact on patronage in the short to medium term. This mode switching may account for up to half or more of the total corridor induced traffic, and an overall increase in corridor traffic of up to 2% to 3% in the short term, but could account for a greater proportion of peak trips and be greater in the longer term.

The evidence is even less clear for on-street public transport modes. There, the reduced road traffic congestion may improve public transport travel time and reliability and make the public transport more attractive to passengers. However, the degree of comparative public transport attractiveness will also depend on the extent to which public transport travel time and reliability are competitive with the new car in-vehicle travel time and reliability, both in the short term and in the longer term.

Any mode switch away from public transport may affect its viability and lead to fare increases or services cuts that could further undermine patronage. However, the equilibrium mechanism will come in to play as road travel times and congestion increase as a result of induced (and diverted) travel over time, and eventually a point can be expected to be reached where both modes will be at a new point of equilibrium.

The response therefore comes down to two simple alternatives:

- Do nothing and expect (and accept) a fare degree of short to medium term mode switching to occur as a natural consequence of the road improvement project, with attendant impacts on the public transport attractiveness and viability.

- Invest in equivalent improvements that improve public transport travel times and reliability and allow it to remain a competitive and attractive alternative to car.

The second alternative is scalable, and could range from minor public transport enhancements that 'hold the fort', to major improvements that aim to match (or better) the road project travel time improvements and grow the overall capacity of the transport system. Where the road project is a bypass that diverts traffic away from an existing road, it may be appropriate to reallocate road space to public transport on the existing road from inception, before induced and diverted travel fill excess road capacity and make it difficult to add in the future. The addition of the Sydney Harbour Bridge bus lane in line with the opening of the Sydney Harbour Tunnel provides a good example of such a project.

Ultimately, more research is needed into the relationship between road traffic congestion and public transport, both generically and at the project-specific level. As transport planners, we both need good information on this relationship and are responsible for assembling it. It is therefore incumbent on us to provide it through better monitoring and analysis.

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