International Transport Forum

Decongesting our Cities

Summary and Conclusions

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The International Transport Forum

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- Juan Pablo Bocarejo (Universidad de Los Andes, Bogotá), "Congestion in Latin American Cities";
- Galit Cohen-Blankshtain (Hebrew University of Jerusalem), Hillel Bar-Gera (Ben-Gurion University of the Negev) and Yoram Shiftan (Technion, Israeli Institute of Technology), "Congestion Pricing with Minimal Public Opposition: The use of HOT lanes and positive incentives in Israel";
- Jonathan Hall (University of Toronto), "High-occupancy Toll Lanes: Their Distributional Impact and Effect on Congestion";
- Robert Poole (Reason Foundation), "The Impact of U.S. HOV and HOT Lanes on Congestion";
- Walter Theseira (Singapore University of Social Sciences), "Congestion Control in Singapore".

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Executive summary

What we did

Congestion undermines productivity and liveability in a large and growing number of cities. This report reviews public policy initiatives implemented to control congestion through pricing and other instruments and analyses them in terms of effectiveness, operational requirements, financial considerations and other aspects of implementation. It includes a particular focus on the impact of high-occupancy toll (HOT) lanes. It also considers the potential for new technology to improve congestion charging systems. The issues addressed include the relative effectiveness and acceptability of different approaches to road pricing and the best means of integrating the range of fiscal and planning tools available to manage traffic and urban land use development. The conclusions are based on discussions between experts and policy makers in an ITF Roundtable meeting held in September 2020 and on previous ITF research. The Roundtable presentations and input papers are available on the ITF website at www.itf-oecd.org/congestion-control-experience-and-recommendations-roundtable.

What we found

Urban traffic management is most effective when transport and land use policies are integrated and designed to use urban land efficiently. This involves review of regulations for the provision of on-street and off-street parking to minimise distortion of land values, and pricing of parking to reflect the opportunity cost of the space allocated to parking. It also involves review of the allocation of space to roads overall and to different categories of road users. Congestion pricing has proved an effective tool for efficient traffic management, especially when it is part of an integrated package of measures for sustainable urban mobility.

New policies that modify road access or charges related to vehicle ownership and use are politically sensitive, raising concerns over fairness and affordability with both motorists and influential stakeholder groups. Successful introduction of congestion charging requires a clear case to be made and prices that have a clearly discernible impact on congestion. The use of revenues to improve alternatives to using cars at peak time is critical to acceptance. Presenting congestion charging in a positive light, as value pricing, or as decongestion charges also appears to improve stakeholder acceptability, as does ensuring that road users have an adequate range of modal choices.

This generally implies that congestion charges should form part of a broader policy package that includes expansion and improvement of other urban transport options, such as public and active transport, micromobility and pedestrian facilities. Reform of public transport pricing to manage crowding in peak periods may also be beneficial where public transport has a large modal share.

Revenue from congestion charges should contribute to funding investments in improving accessibility and mobility regardless of mode. Hypothecation of revenues (i.e. assignment in advance to specific uses) should avoid unduly specific commitments to allow flexibility in directing resources to emerging priorities. Incorporating congestion pricing as part of an overall package of improvements to transport across the metropolitan area, including road investments, has been important to the introduction of some congestion charging systems.

If an integrated approach is adopted, and underpinned by adequate investment in a broader range of transport options, the most sceptical of constituencies can be convinced of the value of pricing strategies to manage congestion, as experience in London, Singapore and Stockholm demonstrates.

The experience with HOT lanes in the United States suggests that this form of direct road use charging faces little opposition from users. In theory, HOT lanes are less efficient than pricing congestion on all lanes of a highway or the entire road network. In practice, HOT lanes have proved a successful tool as part of strategies to manage traffic, particularly useful where access to urban centres relies heavily on limited access highways. HOT lanes are less effective in cities that have little penetration by limited-access highways or those with many local arterial routes into the city centre, like Singapore.

The choice offered by HOT lanes – between using congested general-purpose lanes and reserved lanes that are subject to value-pricing but provide more reliable travel times – is a significant factor in their acceptability. Adoption has also been comparatively smooth because most HOT lanes were implemented as new road capacity, rather than via conversion of existing general-purpose lanes. Thus few, if any, users experienced a reduction in the choices open to them. Concerns regarding equity impacts have proven to be largely unfounded, with users spanning a wide range of income groups.

Dynamic pricing to achieve throughput targets is used on an increasing number of highways in the United States. Users attach much higher value to reliability and to time savings that enable them to meet urgent schedule constraints, than to a reduction in average journey time. This implies that peak toll rates should be set substantially higher than the level that maximises throughput, to leave a buffer that protects users from variability in congestion and traffic disruptions. The frequency of entrance and exit points to HOT lanes makes them particularly suited to dynamic pricing by enabling rapid user responses to changing traffic conditions.

HOT lanes may facilitate the more widespread adoption of road pricing in at least some urban contexts. They create familiarity with road user charging and demonstrate the user benefits of pricing congestion. The successful HOT lane on the highway between Jerusalem and Tel Aviv in Israel confirms the relevance of this approach to managing traffic congestion outside the US, while Canada has also adopted a pilot project in recent years. The Israeli example incorporates a large and successful park-and-ride express bus service free of charge and offers free parking for carpooling. This demonstrates the potential to integrate HOT lanes into broader sustainable mobility policies.

What we recommend

Present congestion charging in a positive light, as value pricing or decongestion charging, rather than as an additional tax

The experience with HOT lanes suggests that users are more willing to pay congestion charges when these are presented as a price paid in exchange for a valuable benefit such as travel time savings, rather than as a tax for imposing delays on others.

Consider congestion charging as part of sustainable urban mobility plans

Cities, particularly in Europe, are increasingly adopting broad policy packages such as Sustainable Urban Mobility Plans (SUMPs). These seek to ensure improved accessibility and mobility as a key element of more liveable cities. Decongestion charging proposals should be considered for inclusion in SUMPs and are likely to be more successful if adopted as an integrated part of such a comprehensive approach to mobility. SUMPs typically include a range of measures aimed at changing mobility habits, including encouraging modal shift to public and active modes of transport, favouring shared mobility and addressing accessibility issues through land use changes, virtual alternatives and other approaches.

Make more use of HOT lanes and peak pricing on tolled expressways

Where urban expressways are already tolled, consider differentiating the tolls to manage peak traffic and improve journey times. City governments and metropolitan transport authorities should explore opportunities for giving public transport services access to express toll lanes and running bus services on HOT lanes.

Ensure adequate user choice to accommodate responses to congestion charging

The behavioural changes prompted by congestion charging necessarily have implications for other areas of transport policy. These should be analysed in the specific context and necessary policy changes made at the outset as part of an integrated approach. Decongesting roads through road pricing will improve the speed and reliability of bus services, enhancing this alternative to car use. Expanding the range and quality of public transport and active mobility options will bring further benefits.

Ensure that congestion charging revenues are used effectively and in ways that have public support

The purposes to which congestion charging revenues are directed are critical to the overall welfare impact of the policy. They are also central to the political viability of the policy, as they influence the level of public support. Revenues should therefore be directed to investments and expenditures that have been prioritised by economic appraisal and public consultation. One clear priority is enhancing public and active transport options to accommodate user responses to congestion charging.

Hypothecate revenues from congestion charges flexibly

Congestion charging revenue provides a potentially significant revenue stream. If this is hypothecated, it should be to expenditure on sustainable mobility options, retaining flexibility to modify allocations as priorities evolve.

Use differentiated congestion charges to maximise the benefits and minimise the costs

Using differentiated pricing allows roads to be used at lower or zero cost outside peak periods. This can help to minimise negative public perceptions of congestion charging policies and ensure that assets are not underutilised outside peak periods.

Introduction

Congestion

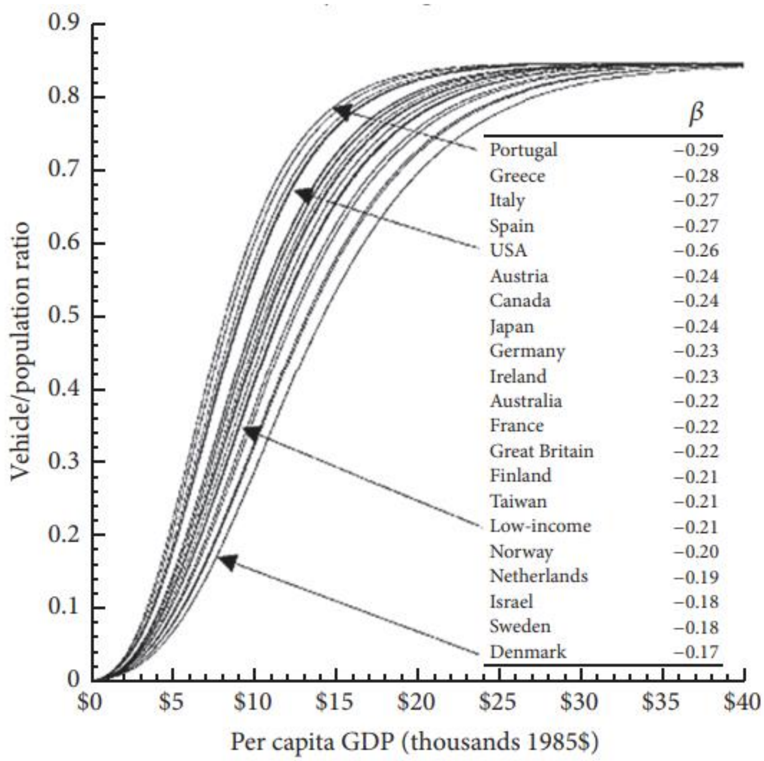
Traffic congestion occurs when the demand for road space rises to a level at which traffic speed noticeably decreases. On a single section of road, it happens when the number of vehicles using it nears its carrying capacity. As traffic speeds fall below their free flowing, or design level, journey times lengthen, increasing the travel time costs borne by each user. Past a certain level of traffic density, the carrying capacity of the road (in terms of throughput per unit of time) becomes unstable and is likely to fall, imposing further costs on users and degrading the ability of the road to carry traffic. Because each additional vehicle entering a congested road space slows the travel speed of other road users, congestion costs are, in large part, external costs. That is, the user does not bear the full cost of their decision to use a congested road. Where negative externalities such as this exist, the usage level of the road can be greater than the social optimum, yielding net welfare losses.

Congestion costs have several components, some more readily apparent than others. The time costs of delays are most obvious, but unreliability of journey times can be considered a distinct category of time costs. Commuters tend to adapt to unreliability by factoring into departure time the delays they experience on days when congestion is particularly bad. This can be double the average delay. These unreliability costs have been estimated by some researchers to account for a large majority of consumers' willingness to pay to use tolled roads or lanes (Bento, Roth and Waxman, 2020). The costs of congestion also include additional fuel costs, as well as health costs due to increased air pollution and stress of driving. While estimates of the monetary value of congestion costs vary greatly, all are large. One study estimated the direct costs of congestion in four major countries (France, Germany, the United Kingdom and the United States) at USD 4 billion in 2013, while adding indirect costs brought the total to over USD 200 billion, or 0.8% of GDP (CEBR, 2014). The authors forecast costs to rise around 50% by 2030.

Increases in urbanisation, city size, and the proportion of the population with access to private vehicles have caused the traffic congestion problem to grow substantially in recent decades throughout most of the world. Bocarejo (2020), surveying six major Latin American cities, finds that while they have seen population growth of 15-32% since the turn of the century, the number of vehicles circulating has increased by 22-100%, with four of the cities seeing vehicle numbers increase by 67% or more. This reflects historical trends, with vehicle ownership rising most rapidly as countries pass through middle-income status, a process that many researchers suggest follows a Gompertz function, as illustrated in Figure 1.

As ITF (2021) concludes, cities need to use scarce space more fairly and efficiently. Managing growth in urban traffic is vital to achieving this and to improving liveability, even if the car will likely be irreplaceable for much travel between peripheral areas. The objective is not to suppress travel by car, but to channel it to locations and uses where its value to the individual clearly exceeds the costs it imposes on society, including other car users.

Figure 1. Long-run vehicle ownership: A family of Gompertz functions



Note: $ = USD.

Source: Lu et al. (2017).

Policy responses to congestion

The traditional policy response to traffic congestion was to build more road capacity. This is now often described as the predict-and-provide model. However, as cities continued to grow and vehicle ownership levels continued to rise, the limits to this approach became apparent. Continued growth, as well as induced demand, have increasingly meant that major road infrastructure investments have failed to deliver sustained travel time reductions. Moreover, there is increasing focus on the amount of scarce land being devoted to road space and the opportunity cost of this land, given the existence of multiple alternative uses in urban areas. This dynamic has been reinforced by increasing recognition of the other external costs associated with high levels of private vehicle use in large, densely-populated cities. These include the health costs associated with crashes, vehicle noise and high levels of air pollution. For all of these reasons, policy makers are increasingly turning to a different range of tools to respond to traffic congestion, based on managing the demand for scarce road space, or providing alternatives to the use of private vehicles, rather than addressing the supply of road space.

Congestion charging has a robust theoretical underpinning. The economic basis is aligning the private incentives of drivers with the social impact of their decisions by levying charges that effectively internalise the costs that their journeys impose on others. Congestion charges can be levied in one of several forms. A cordon charge, as used in Stockholm, imposes a fixed fee on vehicles that enter a designated area in the city centre at times of the day when congestion generally occurs. A cordon charge may be structured as a single daily charge, or as a fee paid each time a vehicle enters the cordoned area. An area charge, as applied in London, is similar but also charges vehicles that travel within the designated area regardless of whether they cross the cordon[1]. A second form is a charge for the use of an individual road link, as used in Singapore beyond its original cordon. A third form is a distance-based charge proportional to the number of kilometres travelled on part or all of the road network. Congestion charges often apply to only one part of a road system. For example, Santiago, Chile applies a time-varying toll to a single expressway running through the city.

Congestion charges seek to reduce congestion by managing demand: driver responses to the charge will generally include a combination of changing the time at which the journey is undertaken, changing the route used to complete the journey, switching to another transport mode to complete the journey and choosing not to travel. This is also true of several other policies that address congestion.

A variant of congestion charging involves pricing one or more express lanes on a highway while retaining free access to other lanes, so that drivers can choose whether to pay a fee in order to save journey time. Most of the express lanes of this sort introduced to date can also be used without charge by high-occupancy vehicles, however defined, resulting in the name high-occupancy toll (HOT) lanes. A two-tier pricing model is a potential variant of this approach, with all lanes being tolled, but with access to one or more lanes being charged at a premium price to improve journey times. Such a policy might be termed a partial or voluntary congestion charge. The fees charged for access to HOT lanes are frequently presented as value pricing – i.e. a payment in exchange for the benefit of a faster journey time. This terminology reflects a view that a fee for service is more readily accepted by public opinion than a charge to internalise a negative externality one's travel choices impose on others. Similarly, the 2018 Mobility Pricing report for Vancouver refers to decongestion charges rather than congestion charges or congestion tolls to more accurately reflect the objective of pricing (Mobility Pricing Independent Commission, 2018).

Other policies that seek to manage the demand for available road space include parking management, licence-plate based selective access restrictions and road space reallocation policies. These measures, plus policies to enhance public transport provision, may need to be adopted in combination with road pricing if efficient land use is to be achieved, but have sometimes been adopted in place of road pricing in response to the political difficulties encountered in attempting to implement congestion charging.

Political economy of congestion charging

Political issues

Despite the broad incidence of the costs of congestion and their large and growing size, governments have generally faced strong opposition when seeking to use pricing to manage congestion. Reflecting this, only a small number of cities, notably including London, Milan, Singapore and Stockholm, have successfully introduced congestion charges. No city in the United States has yet introduced congestion pricing per se, despite the United States having some of the world's most congested cities[2]. However, the United States has developed a growing network of HOT lanes over the past 25 years, with 52 projects totalling almost 3 000 lane kilometres today located in 15 states (FHWA, 2020).

The very limited use of congestion charges globally is notable given that:

- the first such initiative (Singapore's Area Licensing Scheme, an example of cordon pricing) was adopted almost a half century ago, in 1975;
- congestion charges, where introduced, have proven to be effective in reducing traffic volumes and congestion, while also yielding important ancillary benefits[3]; and
- public opposition to congestion charges generally diminishes significantly after the system has been implemented and practical experience with its operation has accumulated (Borjesson et al., 2015).

The limited adoption of congestion charging reflects the fact that city governments seeking to introduce congestion charging have invariably faced strong and sustained opposition from a range of stakeholders. In addition to the motorists who would directly pay the congestion charge, these include businesses in inner urban locations concerned about potential negative impacts on trade and, frequently though not universally, local level municipal governments, which have responded to constituent concerns from both the commercial/retail sectors and residents. For example, when the Greater London Council sought to introduce congestion charges twenty years ago, Westminster Council initiated a legal challenge (supported by Chelsea Borough Council), which was ultimately decided in the High Court. This argued that the charge would "likely increase air pollution and adversely affect quality of life", as well as having negative economic impacts on the central area (Independent, 2013). More recently, Bocarejo (2020) noted that a number of attempts to implement congestion charging in Colombian cities, including Bogotá, have proven unsuccessful due to opposition from municipalities, whose approval has been required in order to adopt them.

It should be noted that in London, once the congestion charge was introduced in the central municipality of the City of London, all of the neighbouring municipalities lobbied to join the scheme, in order to benefit from resident discounts. This highlights the fact that stakeholder opinion is often motivated by the details of what is at stake, not the principle.

In some cases, congestion charging proposals have been defeated by referenda or plebiscites: for example, a proposal to implement the United Kingdom's largest congestion charging zone in Manchester was defeated by referendum in 2008[4], while in 2005, 74% of Edinburgh residents voted against a congestion charging proposal[5]. There were rather specific reasons in each case. The case of Edinburgh is discussed in ITF (2018). In Manchester, the charging proposal gained traction because central government passed a law to grant local government the power to use charging revenues to fund investment in transport infrastructure during a period of austerity, when central government funding for investment was frozen. A change in national policy, releasing large central funds for transport infrastructure, coincided with the referendum on charging, removing the necessity to find a local revenue source. This underlines the fact that the precise context is important in determining public and political attitudes, beyond general principles.

In other cases, the dynamics leading to the defeat of congestion charging proposals have been quite different and political rejection has occurred despite apparently high levels of public support. For example, in the United States, Federal Department of Transportation funding was provided to support development of a congestion charging proposal in New York City in 2006, and a proposal was developed in 2007. However, while polls showed 67% of NYC voters supported the proposal, as did the Mayor of New York City and the Governor of New York State, it failed after one branch of the New York State legislature declined to vote on it (Lassiter, 2016). Altshuler (2010) argues that such proposals face nearly insurmountable barriers in the United States due to the need for approval by many levels of government with differing interests.

ITF research has also highlighted the importance of the financial aspects of congestion charging proposals. For example, the acceptance of congestion charges in Sweden, in both Gothenburg and Stockholm, was underpinned by the overall funding settlements made between central and local government for investment in road infrastructure and in public transport together with charging (ITF, 2018).

In Stockholm, the positive result of the referendum illustrates another aspect of acceptance. Because the vote followed a trial period, citizens were voting on their direct experience of the effect of the cordon charge in managing congestion and its effect on their travel expenditure, rather than on anticipation of what might happen. Regular surveys of public opinion showed that high levels of support continued in Stockholm. This held at least until the most recent round of charge increases, which were designed to raise additional revenues rather than respond to changes in the level of traffic (Börjesson, 2017).

In Singapore, the Land Transport Authority sees the way in which charges are set and revised as important to the overall acceptance of their congestion charge. Tolls are generally reviewed quarterly and adjusted as required to maintain traffic flow. Tolls are increased when average peak hour speed falls below design levels. Conversely, where traffic levels fall, as they did in the early stages of the Covid-19 pandemic, tolls can be reduced or even cancelled. This has made charging more of a technical than a political issue (ITF, 2018). Theseira (2020) shows that Singapore's congestion charging arrangements have been highly effective in maintaining target road speeds over many years, while it has proven possible to apply congestion charging to a progressively larger proportion of the urban road system. However, questions remain regarding the political acceptability of adopting distance-based charging, in place of the current cordon and link-based charging methods, with Theseira noting "… the technological capability to implement advanced forms of road pricing does not translate into the administrative or political capability to do so".

A further challenge relates to the costs and complexity of implementing congestion charging. System administration and revenue collection can account for a large proportion of the gross revenue generated. Costs initially accounted for more than 50% of the gross revenue generated by the London Congestion Charge, although they had declined to around 30% by 2016-17[6]. While technological advances have often been seen as offering means to both enable more sophisticated pricing regimes and reduce collection costs, these expectations have not necessarily been met. For example, Theseira (2020) reports that, while reducing system operating costs was a core rationale for Singapore's planned move to a satellite-based charging system, Global Navigation Satellite System (GNSS), problems with the accuracy of location signals relying solely on satellite signals in high-density areas will require numerous roadside signal supplements. As a result, any cost reductions achieved will be significantly smaller than anticipated.

Another issue is the flexibility given to administrators to make changes to meet identified goals. Laying out the specifics of a proposal, such as the precise fees and times they will be charged, in primary legislation may be helpful or even necessary to get a proposal approved. Yet such provisions can hamper the adjustments inevitably needed as experience is gained and/or circumstances evolve. A change in conditions can then lead to a contentious battle. In Singapore, the law implements the scope and schedule of road pricing charges entirely through secondary legislation, which can be altered as needed by the Ministry of Transport without explicit Parliamentary approval. This has been the legislative practice since the start of road pricing in Singapore and has provided a valuable level of flexibility to administrators. In Bogotá, the government has recently moved to add flexibility to its previous system by giving administrators more scope and reducing the extent of approval needed by the local government.

Responses to the political challenges

Governments aiming to use pricing to manage traffic congestion have responded to the political difficulties associated with introducing congestion charges in several ways. One approach is to tailor the design of the congestion charging scheme to reduce opposition. A second is to address process requirements in ways that make proposals less vulnerable to veto by particular groups. A third is to adopt alternative policy tools that can partially achieve the objectives of congestion charging but which are perceived to be more acceptable to stakeholders.

Tailoring the design of congestion charging schemes

Exemptions are often considered for reducing opposition to charging schemes. Exemptions or discounts may be provided to residents of the area in which the charge operates. This was feasible without severely undermining effectiveness in the initial London scheme because of the very low number of residents within the charging zone, which largely overlapped with the central business district. In mixed land use areas it would undermine efficiency and spatial social equity. In the referenda in Edinburgh and Stockholm support was strongest inside the charging zone, where residents stand to benefit most from traffic reduction, and opposition strongest in the periphery. Exemptions may also apply to commercial drivers – some or all delivery vehicles and taxis – drivers with disabilities, low-polluting vehicles, or others. All exemptions come at a cost, however, in that they reduce the effectiveness of the policy in achieving its main goal of congestion control. Moreover, exemptions and discounts often create new inequities even as they attempt to address previously identified ones. For example, London's congestion charging scheme currently exempts taxis but not ridesourcing vehicles. As the ITF has previously noted (ITF, 2019a), this raises concern regarding competitive neutrality, given the fact that these two groups are close substitutes.

Another design strategy to increase the acceptability of congestion charging is to hypothecate some or all of the revenue to investment in public and/or active transport projects. These both:

- provide direct benefits to those without access to private cars, who have lower incomes on average; and
- enhance car users' ability to shift to alternative modes, thereby avoiding the charge.

The potential for congestion charging to yield substantial revenues implies that hypothecation can have significant impacts in underwriting improved service provision in other transport modes. For example, net income of GBP 162 million from London's congestion charging scheme was used to support public and active transport projects in 2019-20, with congestion charging revenues accounting for 4.3% of all TfL gross revenues and Ultra Low Emission Zone revenues a further 2.6% (Transport for London, 2020).

This approach also enables congestion charging to be more readily promoted as a means of delivering on a sustainable transport agenda. Indeed, in some cases (e.g. the current plan in New York City) the desire to make public transport investments is identified as a primary motivation for introducing the congestion charge.

Process change

Systems of governance differ greatly in the degree to which governmental bodies at various levels can influence the decision-making process. This naturally affects the prospects for a congestion charging proposal to be adopted.

In the case of London, as noted above, significant opposition to congestion charging was encountered from local councils. Some have argued that the policy was ultimately successful due to legislative changes that moved power away from these councils and centralised it in the Greater London Authority.[7] Similarly, in Colombia, the defeat of several congestion charging proposals due to opposition from municipal governments has recently led to legislative change to effectively remove the requirement for municipal agreement to such charges. The national government redefined the nature of the charge in its recent Development Plan (Gobierno del Colombia 2019), defining it as a public price for access to a congested zone. In practice, this change means that governments can implement congestion charging without having to obtain the agreement of municipal councils.

In the Colombian case, this process change was made as part of a broader programme of the Ministry of Transport aimed at relaunching congestion charging as a policy tool at the national level, encouraging congestion charging in cities of more than 300 000 inhabitants. This initiative established a range of process and technological standards, which are intended to ensure high-quality proposals and thereby enhance public acceptance (Bocarejo, 2020).

Political change can sometimes also result in approval for congestion charging proposals without process change. As noted above, a congestion charging proposal failed in New York City in 2007 due to opposition in the State Assembly. A second proposal was defeated in the State Assembly more than a decade later, in 2018. Yet a similar proposal was adopted by the same body only a year later, and is expected to be implemented in 2021 (ITF, 2019a).

King et al. (2007) argue that, rather than creating more winners than losers, tolling schemes should be designed so they create a strong lobby group in their favour. King et al. propose giving revenues from highway tolls to the governments of the municipalities through which the tolled roads pass. In addition to potentially increasing the political viability of congestion charging proposals, such an approach can also be considered equitable, in that these municipalities bear the local external costs of congestion and pollution.

Alternative policy options

A range of congestion control tools exist and work best as part of an integrated policy approach that makes appropriate use of a full range of measures. In the most effective traffic management systems congestion charging, if used at all, is supported by other measures to manage car ownership as well as road use, as in Singapore and Tokyo (ITF, 2019b).

Some such measures can be considered as indirect approaches to congestion pricing, and may be perceived by governments as more politically feasible and, hence, as acceptable second-best policy options. For example, a wide range of cities in Australia, Canada and the United States have implemented various quantity controls and taxes on parking. Large changes to parking supply and price can have a significant impact on modal choice.

The incentive effects of such parking policies can be mixed, with some impacts being contrary to the underlying congestion control purpose. For example, commercial parking taxes can give rise to incentives for increased provision of unpriced parking spaces. For these reasons, per space levies are generally preferable to other alternatives (Littman, 2013). Moreover parking taxes and supply management initiatives have themselves proven politically controversial in many cases. Reducing the supply of on-street parking spaces or significantly increasing their cost is likely to be strongly opposed by the retail and commercial sectors, notwithstanding evidence that concerns over negative impacts on trade are generally misplaced (Fleming, Turner and Tarjomi, 2013).

Road space reallocation is sometimes viewed as an alternative to congestion charging, particularly where there is an emphasis on mode shift to meet multiple goals. This commonly includes installing bicycle lanes, improving pedestrian infrastructure or reserving certain traffic lanes for buses or high-occupancy vehicles (HOVs). Such policies have also frequently proved controversial, particularly due to concerns that they will worsen congestion. Such concerns can materialise in practice, especially in the absence of complementary policies to support modal shift; but the reversal of induced demand that occurs when road space for cars is reduced will somewhat mitigate the congestion impact. In Oslo, for example, recent reductions in trunk radial road capacity have seen no increases in congestion (ITF, 2021).

In sum, the political acceptability of other congestion control measures is heavily dependent on the context in which they are introduced, with a similar range of factors being relevant to those that affect the acceptability of congestion charging. Either type of policy is more likely to achieve acceptability if it is part of a broader policy framework that offers choices to travellers, addresses key equity impacts and uses any significant revenue generated to support the underlying policy objectives.

HOT lanes as a voluntary congestion charge

One form of congestion pricing is link-based, as noted earlier, in which payment is made for use of a specific stretch of road. HOT lanes can be considered a variant of the link-based charging model, in which only a subset of the lanes are tolled. Thus users of a particular stretch of road can choose whether to pay a toll in order to obtain time savings and greater journey time reliability, or avoid it. Because these restricted-use lanes run parallel to untolled general purpose lanes, it is a real choice; and typically users can choose differently on different days, or move between lanes in the course of a single trip.

Development and impact of partial pricing

The term partial pricing is used here to denote fees that are time- and space-specific, like full congestion pricing, but apply only to a portion of the relevant infrastructure. A number of different models of partial or differentiated pricing of roadways can be distinguished:

- HOT lanes, which provide low- or zero-cost access to HOVs, with varying eligibility rules, and tolled access for other vehicles;
- Express toll lanes, which provide toll-free access only to specified vehicles, usually buses, and tolled access to other vehicles;
- Two-tier pricing, which offers access to premium lanes at a higher price and charges a lower price on the general purpose lanes (Small et al., 2006).

Historical Development of HOT lanes

HOT lanes appear only to have been implemented in the United States (AHB35, 2019), with the exception of one project in Israel (Cohen-Blankshtain et al., 2020) and a recent Canadian pilot project. After a slow start, this model spread rapidly in the United States. The Federal Highway Administration (FHWA, 2020) now counts 52 operational projects, developed over a 25-year period.

Historically, HOT lanes have developed in at least two different ways. The first is traced by Poole (2020), who highlights the following key steps:

- The initial adoption of bus-only lanes during the rebuilding of a number of expressways in the 1960s and 1970s;
- Adaptation of these bus lanes to become HOV lanes, which allowed access to vehicles carrying more than a threshold number of passengers (i.e. carpools and vanpools) in the 1990s and 2000s, as a means of improving capacity utilisation and reducing overall fuel consumption and emissions;
- Further evolution of HOV into HOT lanes, which enable low-occupancy vehicles tolled access to the lanes, which remain accessible without charge to qualifying HOVs. This further improves capacity utilisation by enabling the transport authority to adjust the toll level so as to closely match traffic flow to capacity.[8]

The second means by which HOT lanes have developed is as part of projects that add capacity to existing expressways, often funded as Public-Private Partnerships (PPPs). In this model, tolls are an important revenue source contributing towards financing the new capacity.

In practice, there has been a clear trend away from the first model and towards the second. Moreover, where HOV lanes have been converted to HOT lanes, the occupancy levels required to obtain toll-free travel have tended to increase over time (Poole, 2020).

While HOT lanes have largely developed in one country to date, the partial tolling approach could potentially be adopted in a wider range of countries, and may represent a feasible substitute and/or complement to full congestion charging in certain circumstances. It may also represent a means of expanding the use of road user charging and potentially provide a stepping stone towards full road user charging. The accumulated practical experience in implementing HOT lanes may also provide valuable lessons for the design and implementation of other congestion charging models.

Benefits of partial tolling

Partial tolling of a road with HOT lanes enables those with a low value of travel time (VOTT) to travel the same route and avoid the toll, in effect paying in time rather than money. However, while the proportion of tolled lanes is typically no more than half of the total, the HOT lane alternative can yield a large percentage of the available gains from congestion charging.

HOT lanes are a second-best policy, both because the application of tolls is restricted to a subset of lanes of a single road and because HOV vehicles are either exempt from payment or given a discount, despite imposing the same congestion as a single occupant vehicle.[9] However, in at least some circumstances, a high proportion of the theoretical benefits of a generally applicable congestion charge can be obtained via HOT lane charging, while distributional outcomes may be significantly better. For example, Hall (2020a) contrasts HOT lanes with full link-based congestion pricing in terms of both aggregate and individual impacts. His analysis concludes that tolling all lanes yields a potential benefit of USD 2 400 per annum per road user, but the benefits are not evenly distributed: individuals with a very low VOTT and inelastic preferences regarding arrival times are up to USD 2 390 worse off. By contrast, if only half of the available lanes are tolled, nearly three-quarters of the benefit from applying an optimal toll to the whole road can still be attained. Moreover the benefits are much more widespread, especially if HOT lanes are implemented as additional capacity on existing roads. In that case, any diversion of traffic from the existing general purpose lanes to the new HOT lanes necessarily reduces congestion on the general purpose lanes, benefiting the lower-VOTT users who use them. This can lead to a Pareto improvement, meaning everyone benefits (even without considering the use of toll revenues): those who choose to use the HOT lane reap the largest benefit from travelling on a congestion-free road, while those who continue to use the general purpose lanes also benefit due to reduced congestion.

Hall highlights the size of the available welfare benefits, concluding (on the basis of Californian preference distributions and city-specific vehicle-kilometres travelled [VKT] and congestion data) that "extrapolating my results to the rest of the United States suggests that pricing half the lanes on urban highways would increase social welfare by over USD 30 billion per year, without hurting any road users." This is equivalent to about USD 850 per user per annum. The ability to generate a Pareto improvement in the absence of compensating transfers of the toll revenue is significant in light of the practical difficulties typically encountered in making such transfers.

However, to the extent that reductions in congestion on the road to which a HOT lane is added induce additional demand, there are likely to be offsetting increases in congestion on other parts of the road network. These second-round impacts may mean that a Pareto improvement is not achieved across the broader road network, at least without taking the uses of toll revenues into account.

A notable aspect of the "voluntary" characteristic of HOT lanes is that a high proportion of users make use of the HOT lane option only infrequently, while a smaller proportion uses it regularly. Thus, for most individuals, their VOTT is high enough to make paying the toll the optimal choice only in certain circumstances. For example, Cohen-Blankshtain et al. (2020) report that in the case of the Jerusalem-Tel Aviv HOT lane, 56% of paying users in 2014-15 used the HOT lane only once during the course of the year, 30% used it two to five times and only 6% used it more than 11 times. Similarly, Poole (2020) reports that a recent extensive study by Hallenbeck et al. (2019) confirms "an informal rule of thumb among HOT lane traffic forecasters that 90% of the users are in the lanes only occasionally while 10% of them use the lanes very often."

Combining HOT lanes and other congestion-reduction initiatives

While HOT lanes appear to have developed as stand-alone measures in the United States, Israeli experience demonstrates the potential to combine a HOT lane with other congestion-reduction initiatives.

The Tel Aviv HOT lane

The HOT lane was added to the Jerusalem-Tel Aviv highway in 2011, running from near the international airport to the central expressway in Tel Aviv. Cohen-Blankshtain et al. (2020) highlight the establishment of a free shuttle service along the HOT lane. This enables commuters to complete their journey by driving to a free carpark adjacent to the HOT lane and boarding one of two high-frequency, free shuttle buses that serve different areas within the Tel Aviv central business district. Commuters who choose this option are also able to use the first part of the HOT lane without charge to reach the free carpark.

This initiative is financed by government payments to the private operator of the HOT lane in respect of each car parked by users of the shuttle bus service or of a carpool vehicle using the HOT lane.[10] These payments seem likely to have significantly increased take-up, given that parking cost savings were found to be a significant factor in the choice to use the shuttle bus service (72% of users reported not having reserved parking available at their destination). This, in turn, highlights the potential for co-ordinated action to maximise the use of the shuttle service, by acting on the price and/or supply of city-centre parking.

The shuttle bus initiative appears to have had a significant additional congestion-reducing impact. Shuttle bus frequency is three times as great during peak periods as other times of the day and surveys show 92% of trips in the shuttle buses to be work-related. Moreover, 56% of survey respondents stated that they used their car to complete the equivalent journey prior to the operation of the shuttle bus service. The remaining 44% had switched to the new shuttle service from other public transport services.

Journey time reliability, a function of the shuttle using the HOT lane, was cited by 95% of shuttle bus users as a key factor in their choice of this mode. Thus, one significant impact of the Israeli HOT lane is that it has provided an opportunity to improve the standard of public transport services. The Roundtable did not examine in detail the extent to which this element of the Israeli experience may be transferrable to other contexts. However, in the absence of obvious impediments, this appears to be an important topic for further consideration in analysing the potential impact of HOT lanes. Moreover, while explicit incentives to use public transport do not appear to be a feature of the US HOT lane experience to date, Poole (2020) notes that the access to uncongested roadways, which the establishment of a HOT lane creates, effectively makes public transport more attractive by improving journey times and reliability.

Another option for commuters using the Israeli HOT lane is to travel by carpool, hence obtaining free access to the HOT lane and use of the free carpark. Thus, the policy stance surrounding the HOT lane includes active encouragement of carpooling. This is a notable point in the context of US data cited by Poole (2020), showing a substantial long-term decline in carpooling.[11] Free parking facilities might be incorporated at strategic points on US HOT lanes to reverse this trend. Finally, the Tel Aviv free carpark also serves as the terminus for a number of standard bus routes, providing a further incentive (in addition to the free shuttle bus) for the use of public transport, and a further low-cost option (free HOT lane followed by standard transit bus) for those who carpool.

Potential for wider adoption of the HOT lane model

The United States has now accumulated some 25 years of experience with HOT lanes, during which their use has expanded quite strongly. HOT lanes exhibit significantly better capacity utilisation performance than either bus-only lanes or HOV lanes, while avoiding congestion and maintaining travel speeds, thus demonstrating that efficient pricing can be applied in practice, at least in this form. It is notable that this form of congestion charging appears to have been adopted nowhere else, other than the single project found in Israel and as a pilot project adopted in Canada in recent years.[12] The Roundtable did not reach a clear conclusion as to why this has been the case, but discussed the potential for similar initiatives to be adopted in other contexts.

It was noted that the express bus lanes are quite heavily utilised in a number of densely-populated Latin American cities (in contrast to many other circumstances). This leaves relatively little scope for their conversion to HOT lanes, while there is limited ability to add capacity due to spatial constraints. Conversely, the Roundtable discussed the potential to provide free access for buses and vanpools to one or more lanes of currently tolled expressways in cities such as Mexico City and Santiago. Such initiatives would require the renegotiation of existing toll concessions with expressway operators, but would have similar incentive effects to an HOV lane.

In general, it appears that, at least where there is potential to increase overall road capacity, there is no obvious impediment to the adoption of the HOT lane model in a wider range of countries. The ability to present the toll paid in terms of value pricing provides a potentially significant benefit in terms of public acceptability, as discussed further below.

Issues in implementing congestion charging

This section identifies two broad categories of issue in implementing congestion charging. The first is issues that arise in determining how to set, implement and enforce prices. The second is the range of strategies that have been or could potentially be, adopted improve the acceptability of congestion charging to stakeholders.

Design and implementation

Economic theory holds that the benefits of congestion charging are maximised when charges are set at a level that internalises the cost individuals impose on other users due to the increase in travel times an additional vehicle causes in congested conditions. However, there are significant practical impediments to both identifying such prices and levying charges in practice. The Roundtable therefore included discussion of a range of alternative price-setting options and issues associated with their practical implementation.

Cordon vs. segment (or route) pricing

Congestion pricing has been implemented through several spatial charging models including charges for crossing a cordon, charges for driving on roads within a designated area of the network and charges on specific highways or road segments. London and Stockholm, as already mentioned, have implemented area pricing and cordon pricing, respectively. The scheme being planned for New York City is also an example of cordon pricing. Singapore initially applied a paper-based area charge that has evolved into an electronic fee collection system combining a cordon around the central business district with charges on segments of the surrounding highway network, as well as some other arterial road sections.

Anas and Hiramatsu (2013) used a general equilibrium model, including housing and land use, to model various cordon charges in Chicago. This shows that an optimally-located cordon could achieve nearly two-thirds the welfare gains of ideal congestion pricing, but that the gains depend heavily on the location of the cordon. Similarly, May et al. (2008) showed that potential gains of cordon charges in Edinburgh and other UK cities varied greatly with cordon design, often finding that oddly shaped and/or multiple concentric cordons worked best, and that many of the gains could be achieved by pricing selective links crossing the cordon rather than all of them.

There are also distinctions within the broad category of cordon pricing. Thus, the model used in central London levies a single, daily charge on any vehicle that either enters the cordon area or drives within it between 7 a.m. and 10 p.m., regardless of the time of day the cordon is crossed. Conversely, the model adopted in Stockholm both:

- Varies the size of the charge according to the time of day the threshold is crossed; and
- Levies the charge each time the vehicle crosses the cordon, whether entering or exiting the central area.

The current congestion charging proposal for Bogotá combines a single cordon entry fee, set at a modest level, and a fee per kilometre within the cordon, making it something of a hybrid between cordon and distance-based fees (Bocarejo, 2020).

These different cordon pricing models have different incentive effects. A charge that is differentiated according to the time of day at which the journey occurs tends to encourage motorists to modify their journey time, spreading demand more evenly throughout the day. Conversely, a large, undifferentiated charge as adopted in London is more oriented towards incentivising modal shift away from private vehicles. Second, levying a charge each time the cordon is crossed increases the size of the incentive effect for vehicles that undertake numerous daily journeys into and out of the charged area, such as ridesourcing vehicles. For example, adoption of the Electronic Road Pricing System in Singapore shifted the charge from being fixed for the day to marginal per entry and resulted in a significant drop in traffic in the central business district even though the new marginal charges were initially set lower than the previous fixed charge (Phang and Toh, 2004). Such a charge can be seen as more efficient, in that it varies more closely with the size of the congestion impact individual vehicles have over the course of the day. The proposal in Bogotá seeks to leverage this incentive by also charging per kilometre driven in the most congested area.

A notable aspect of long-established cordon charges is that the size of the charge varies only infrequently. For example, Stockholm's charges, first adopted as a permanent scheme in 2007, have been revised only once, in 2016, almost a decade after their introduction. The London Congestion Charge has been amended only four times in the 17 years since its adoption, while the charge paid by private cars under Singapore's former Area Licensing Scheme (ALS) changed four times during its 23-year existence, being both increased and decreased during this time (Foo, 1997).[13] The apparent unwillingness of policy makers to vary cordon charges is notable given the limited analysis that appears to have underpinned the choice of the initial charging level in most cases. For example, Theseira (2020) notes that following the large initial drop in vehicle throughput in central Singapore after the initial introduction of the ALS, most economists believed that the fee of SGD 3 was too large to be optimal. Yet it was increased twice, reaching SGD 5 in 1980, before being reduced to its initial level in 1989, 14 years after introduction.

By contrast, the use of segment pricing appears to be associated with much more frequent price adjustments. The reason for this difference is not obvious, but may be related to the politics of establishing a single charge applying to everyone, which creates a strong focal point for discussion and criticism. Another possible explanation is that cordon tolls are generally set at the same level for all entry and/or exit points. Since the optimal time profile of the charge is likely to vary by location, little would be gained by trying to adjust the toll "optimally" in short time intervals.

In 1998, Singapore introduced a rules-based pricing system for the electronic toll collection system currently in place, with a pricing formula developed using the traffic flow model of the Land Transport Authority. Prices are set to maintain traffic speeds at 20-30 km/h on arterial city roads and 45-65 km/h on expressways. Prices at each toll gate are determined by a quarterly review of traffic speeds. When speeds fall below the target levels on the adjoining road segments, prices are increased. When speeds rise above the target range, prices are reduced. This mechanism underpins public support for the system, making the link between charge and congestion level transparent, and permits prices to be modified without having to revert to a political decision each time changes are required (ITF, 2018; Theseira, 2020).

Fixed vs. variable pricing, anticipatory and dynamic tolling

One key distinction is between a fee that is fixed during a stated period (such as weekday business hours) and one that varies with time. In the variable case, a second key distinction can be made: between predictive (or anticipatory) pricing and dynamic (or real-time) pricing. Predictive pricing involves periodically resetting prices on the basis of analysis of recent traffic data and toll levels, followed by revisions to the toll level intended to more closely approach relevant targets, such as vehicle throughput or average speed. Thus the toll is fixed over a set period, such as a few months. Singapore's system is largely an example of predictive pricing, with toll levels reviewed and adjusted quarterly on the basis of speed-flow traffic studies, though the twice-annual toll reductions during school holiday periods are examples of anticipatory pricing.

Real-time, or dynamic pricing, by contrast, involves resetting prices at very frequent intervals in response to real-time monitoring of traffic conditions. This process can include anticipating future incoming traffic, as well as the number of vehicles currently entering the system. For example, Carey and Srinivasan (1993) derived optimal dynamic congestion tolls on a general network and showed that the optimal toll includes not only a static component, which depends on the instantaneous congestion level, but also a dynamic component that is positive if congestion is increasing and negative if it is decreasing.

Real-time pricing is used in practice in many of the HOT lanes currently operating in the United States, with prices typically updating at intervals of five minutes or less. It is also used in the Israeli case.

Gardner et al. (2014) examined various toll schemes, both fixed and variable, for HOT lanes to attempt to identify robust pricing policies. The authors concluded that a fixed toll can achieve about two-thirds of the potential benefit of an ideal HOT lane tolling system. While a variable toll based on anticipatory pricing can achieve some additional welfare benefits over the fixed toll, the extent of the variation in demand over time necessarily determines the size of this additional benefit.[14] That is, if demand varies in less predictable ways, the additional benefits of a variable toll based on anticipatory pricing, relative to a fixed toll, are more limited.

By implication, in such circumstances, tolling based on real-time data (i.e. dynamic tolling) is needed if significantly better outcomes than those achievable via a single, fixed toll are to be obtained. Indeed, the authors find that a relatively simple real-time tolling system has practically equivalent performance to the ideal tolling system. However, dynamic tolling is only feasible in specific circumstances: drivers must have the ability to choose whether to pay the toll, based on the updated pricing information. This can be done either by announcing the toll well before a driver must decide whether to take the tolled route, or by tolling different segments of the road separately, where there are opportunities to exit to untolled lanes or use alternative routes between each segment.

A key advantage of predictive pricing is that it provides a high level of transparency and certainty to users regarding the prices they will pay to use a section of road. A quarterly price reset, such as that used in Singapore, provides time for government to announce and explain price changes in advance of their adoption, while users have a clear understanding of the price level before deciding whether to use the toll road.

In Singapore, the predictive pricing model is used to maximise vehicle flow on congested routes. Theseira (2020) states that this target has been adopted on the assumption that it will also approximate the socially efficient outcome, in which the private and social marginal cost of driving are aligned. However, he notes that it is unclear to what extent this objective has been achieved in practice, as there has been no recently published or updated study of the welfare effects of the congestion pricing system, nor any estimate of the demand function for the roads on which it is applied. A key issue in this regard is the lack of published official data on key variables, which has meant that there have been few academic studies of its performance. However, average speed data are published periodically, and show that there has been a high level of success in meeting average speed targets. From 2005 to 2014, average expressway speeds ranged from 61.2 km/h to 64.1 km/h, which is at the upper end of the target speed range of 45-65 km/h. Similarly, CBD/arterial road speeds averaged 26.6-28.9 km/h, also near the upper end of the target band of 20-30 km/h (Theseira, 2020). These results have been achieved in a context in which the size of the vehicle fleet grew by around one third over the period. Thus, Singapore's experience provides clear evidence of the ability of a predictive pricing model to address congestion effectively over time, despite significantly increasing demand.

Moreover, the Singaporean approach to price setting is an iterative one, as distinct from being based on engineering calculations or the direct estimation of demand functions. The effective achievement of target parameter values over a lengthy period via an iterative, or trial-and-error approach is consistent with the conclusions of researchers. For example, Ye, Yang and Tan (2015) find that "the trial-and-error procedure is capable of learning the system optimum link tolls without requirement of explicit knowledge on the demand functions and flow evolution mechanisms" (see also Yang, Shu and He, 2010).

Real-time pricing requires the constant monitoring of vehicle throughput and/or speeds during high-demand periods, together with the development of an algorithm relating these variables to changes in the toll to be applied. A key issue in relation to the algorithm is whether toll-setting should respond only to traffic conditions in the HOT lane or whether it should also take account of conditions in the neighbouring general purpose lanes. Some analysis suggests that the latter approach may lead to unduly high tolls and consequent underutilisation of the HOT lane, as an operator who guarantees free-flow travel time in the HOT lanes may be forced to set unreasonably high tolls to deter excess demand, worsening the conditions in the general purpose lanes (Laval et al., 2015).

A further issue is that some research has found that, across certain toll price parameters, drivers are more likely to choose the HOT lane when the price is higher, as the size of the toll is apparently used as an indicator of the severity of the congestion likely to be encountered in the general purpose lane.[15] Other findings differ on this issue (e.g. Brent and Gross, 2017). This suggests the need to communicate information on both tolls and expected travel time savings in order to facilitate informed user choices, as is done in the Californian HOT lanes.

A key benefit of dynamic pricing over predictive pricing is that it enables prices to respond almost instantly to unexpected changes in demand or capacity and, to the extent that such changes arise, can be expected to yield a superior performance outcome. This will evidently be a more significant source of benefit where the predictability of variations in demand is lower. However, the fact that the toll to be applied cannot, by definition, be known until users near the beginning of the tolled segment means that dynamic tolling can only produce an appropriate behavioural response where users have a choice as to whether or not to use the tolled road. This has effectively meant that dynamic pricing is adopted in practice only in the context of HOT lanes, where rapid switching to parallel general purpose lanes is feasible.

In sum, the relative merits of predictive and dynamic pricing depend on the specific conditions in which they are adopted. A key factor is whether the relevant population is familiar with time varying prices, as it appears that such familiarity tends to increase the acceptability of dynamic pricing. At the same time, care should be taken to avoid unnecessary complexity in structuring pricing models, which consumers can struggle to assimilate. This implies that there can be advantages in adopting second-best pricing approaches.

Price setting: Targets and proxy measures

As noted, tolls set on the basis of a target for vehicle throughput or average speed can provide a good approximation of an optimum toll. Conversely, a revenue-maximising toll would not necessarily perform well; indeed, some simulation studies have suggested that the unregulated profit-maximising price yields lower welfare outcomes than having no price. This leads to the conclusion that appropriate regulation of pricing is required where privately-run tolled roads are concerned.

Vehicle throughput targets

A high proportion of US HOT lanes set prices based on a vehicle throughput target, expressed in terms of a critical flow that should not be exceeded (Goodin et al., 2011). There is a relatively high degree of commonality in the specific targets adopted, as shown in Table 1. However, Cohen-Blankshtain et al. (2020) note that it is unclear whether these policies have been adopted with the goal of ensuring an adequate level of service in the HOT lanes, or whether they are seen as constituting full utilisation.

Table 1. Vehicle throughput targets on selected US HOT lanes

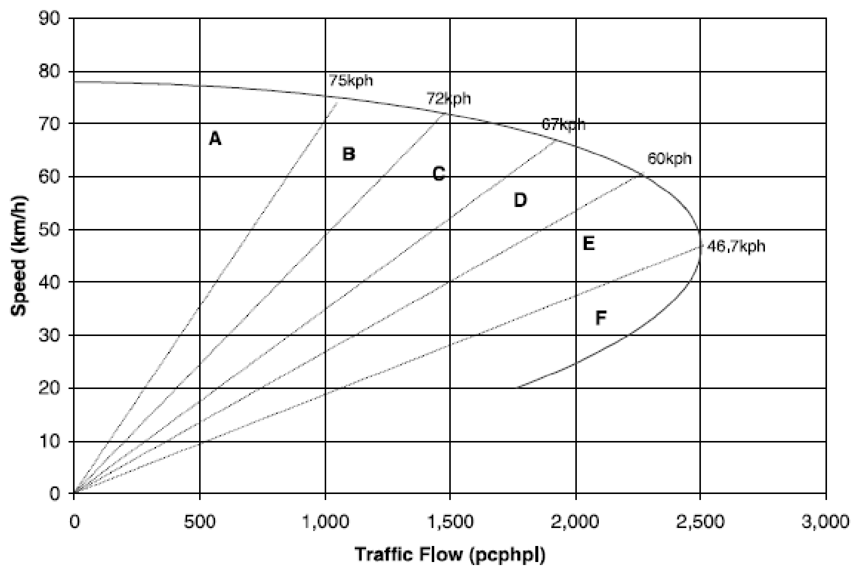
HOT lane	Throughput target (vehicles per hour per lane)
SR-91 (California)	1 360-1 600
I-25 (Colorado)	1 150
I-10 (Texas)	1 300
I-15 (California)	1 350
El Monte Busway (California)	1 300 passenger car equivalents[16]

Source: Goodin et al. (2011).

While such throughput targets are likely to represent a sound proxy rule on expressways, speed-flow relationships are more complex on city streets, due to factors such as intersection blockages, so that greater difficulty will be encountered in using this as a target variable in this context. This perhaps suggests there is merit to the use of iterative approaches to setting target values, with monitoring of other key variables.

In contrast to the US HOT lane experience, Singaporean authorities have adopted road speed targets as the basis for price setting. The Singapore Land Transport Authority (LTA) uses the speed-flow relationship reproduced as Figure 2 as the basis for this iterative pricing process. The iterative pricing model is used to keep speed and flow within regions D and E, in which significantly higher flow rates are achieved with acceptable declines in average speeds, and prevent movement to region F, where both speed and flow are reduced (Theseira, 2020).

Figure 2. Speed-flow relationship for Singapore expressways



Source: Li (2002), reproduced in Theseira (2020).

Theseira argues that LTA's pricing strategy is based on the assumption that, by keeping vehicle flow close to its maximum, the efficient outcome (in which the social marginal cost of driving is aligned with the private marginal cost) will be approximated. However, this assumption appears to remain essentially unverified. No official attempts to estimate the welfare effects of the congestion pricing system have been published.

Price-setting, the value of reliability and urgency

Much of the research on which the analyses just described is based uses the value of time savings as the key measure of the benefits of lower congestion. However, recent research suggests that reliability, i.e. the predictability of the travel time required to complete a trip, may be more important to drivers. For example, Brent and Gross (2017) find that drivers primarily value travel reliability over time savings when using HOT lanes, with the former estimated to be valued more than three times as highly as the latter. At the same time there is heterogeneity in the relative values of time and reliability based on time of day and destination to or from work. They conclude that "these results suggest that the simple estimates of value of time on HOT lanes overestimate the true value of time, and that much of the purchase decision is actually based on improved reliability."

When this is taken into account, it suggests an optimum where the targeted throughput is below the potential maximum, since occasional fluctuations will otherwise cause movement into Region F in Figure 2, with costly results. Modelling by Hall and Savage (2019) finds that, for this reason, throughput targets should be set at levels around 15% below the level that would maximise expected throughput. Unreliability is due to many factors, such as demand fluctuations, capacity fluctuations (due to weather, roadworks, or accidents), and driver behaviours such as aggressive lane changing. Some of these factors are more likely to occur when roads become congested.

Similarly, Bento et al. (2020) highlight the importance of the concept of urgency when assessing the value of travel time (VOTT) savings and, hence, the welfare impact of tolling. The value of urgency is a product of the fact that individuals often face discrete penalties for being late. Bento et al. distinguish the value of time savings in immediate, urgent circumstances, such as running late for an appointment, from the value of reliability as usually defined. The latter deals with the average properties of the distribution of travel times, whereas Bento et al. defines the value of urgency in the following terms: “Urgency is the valuation of a discrete amount of time saving needed to be as close as possible to meeting your schedule constraint”. They calculate that the value of urgency accounts for as much as 87% of the total willingness to pay for VOTT savings, highlighting the importance of ensuring that these values are taken into account in setting tolls. Equally important, a high value of urgency increases the value to users of having real-time options for time savings that become available while *en route*, as occurs with HOT lanes that have adopted real-time pricing.

Effect of other policy settings on the incentive effects of congestion pricing

Theseira (2020) highlights the policy the Singaporean government has long followed of using road pricing as a means of shifting vehicle taxes away from ownership to usage, thereby allowing expansion of vehicle ownership (which is controlled by quotas and hence expensive) to a larger proportion of the population. This may be one reason for the public acceptability of road user charging in a context in which there is an expectation of a high level of vehicle-based taxation.

This example highlights the impact of other vehicle-related policies on the effectiveness of road user charging as a policy tool. Some researchers speculate that Singapore has reached the limits of using road tolls to contain traffic as if the fixed costs of car ownership are very high, then even relatively large road user charges will add only modestly to the total ownership cost. In these circumstances, the incentive for car owners to gain full value for their substantial investment in the fixed costs of vehicle ownership may mean that road user charges have a relatively limited incentive effect – and thus, limited effectiveness as a policy tool (Ho, Png and Reza, 2017).

The specific design of the congestion charging system is also an important determinant of the size of its practical impact. From the perspective of ensuring appropriate incentives, a charge that varies directly with the distance driven on congested roads is usually preferable, unless there is a specific choke point where the need for demand restraint is concentrated. This is because designs based instead on a “threshold” charge, such as a single daily charge, may create incentives to increase trip numbers for people who have already decided to pay the threshold charge. That is, if charging is based on a single, daily (or other periodic) charge for access to the congested road network, there is no incentive for drivers to minimise the number of trips taken within the period. Some may, in fact, perceive a positive incentive to undertake additional trips to obtain value for the charge already paid. On the other hand, threshold charges are likely to entail lower collection and enforcement costs. Decision makers must balance the relative importance of these factors in their specific circumstances.

Compliance issues: Collection and enforcement

Researchers have drawn conflicting conclusions regarding the nature of the trade-off between simplicity and incentive effects. Some have found high collection costs for cordon charges when they were initially introduced (e.g. Jansson, 2008 for London and Stockholm). However, the administration costs of these schemes have declined as a proportion of gross revenue over time. In London, as noted above, administration costs declined from over 50% of gross revenue in the early years of London’s congestion charge to around 30% in the latter part of the last decade. In Stockholm, costs fell greatly between the trial operation phase and reintroduction as costly parts of the vehicle identification system were found to be redundant.

The case of Singapore is also notable. The collection cost of the current Electronic Road Pricing (ERP) system is relatively high, due to the need to construct roadside gantry infrastructure. This cost, plus concern over the unsightly nature of the gantries, constituted an impediment to the expansion of the area covered by the congestion charging system. Cost reduction therefore formed a key objective of the planned move to a satellite-based (GNSS) system. However, field testing showed that the accuracy of global positioning satellites (GPS) at pinpointing locations was inadequate for charging purposes at some locations in the most densely built-up areas. This necessitated the installation of an array of roadside units, each with radio communication to nearby cars. The on-board unit required by the GNSS is more advanced than current ones, adding to cost. The cost savings from moving to the new satellite-based collection system are therefore likely to be significantly smaller than anticipated. However, it will offer greater flexibility in extending tolling as the road network expands and in responding to changing patterns of demand.

Theseira (2020) notes that the long gestation period of the GNSS system, needed to address these and other issues, has also lead to technological developments rendering key assumptions of the initial system design questionable or invalid. In particular, while it was intended that the dedicated “on-board units” (OBUs) to be installed in each vehicle would be used to deliver other value-added services (such as traffic information), the rapid dissemination of smartphones has largely eliminated this as a prospective added-value item. The same development has also raised the question, now being considered by the government, as to whether purpose-specific OBUs should be replaced altogether by motorists’ smartphones (Yong, 2020).

Enforcement

The enforcement of cordon charges and electronic toll collection relies on cameras equipped with automated licence plate recognition to identify vehicles that are not associated with a payment record. The costs of the technology itself are relatively small, with the costs of the enforcement system driven by the back office record processing system adopted and the way the law assigns responsibility for unpaid use of the road. Exemptions for high-occupancy vehicles, however, pose problems as video surveillance is not good a detecting how many people are inside cars. Poole (2020) notes that, despite a quarter century of experience with HOT lanes, the issue of effective enforcement of its requirements has yet to be addressed satisfactorily, especially regarding HOV definitions and whatever exemptions may apply. The “presence of numerous cheaters reduces the pricing power of variable tolling and thereby reduces the congestion-reduction benefits”. Technological advance has led to a number of new approaches being investigated and tested in recent years, including improved camera monitoring systems and smartphone-based systems. However, none has yet been widely adopted or recognised as highly reliable. In systems other than HOT lanes, the preferred solution is to eliminate, or at least severely limit, the categories of vehicles that are exempted from the toll.

Network pricing

Despite the rapid expansion in the number of miles of HOT lanes in operation in the United States, these facilities largely continue to operate on an individual basis, rather than being integrated into a tolled network. Increasing investment in HOT lane facilities can be expected to lead to more individual journeys that involve travel on more than one HOT lane. This will raise two issues. First, users will place great value on the ability to transition from one HOT lane to another smoothly, without having to exit the HOT system and navigate highly congested interchanges, as now often happens. This may require costly expansion and/or reconfiguration of interchanges. Second, setting prices to achieve either a speed goal or a throughput goal will become a more complex task. Where these issues are overcome, the development of functional HOT lane networks has the potential to expand significantly the value of HOT lanes to consumers, including by making total trip times more reliable.

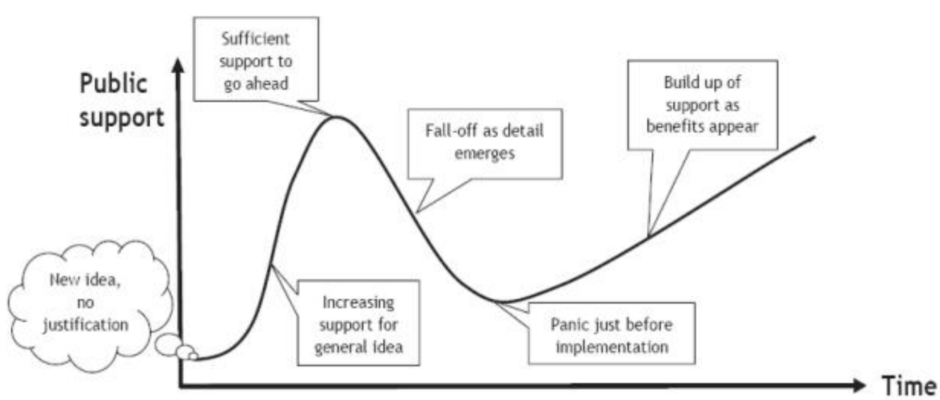
Whether or not there is an explicit HOT lane network, it is important to remember that HOT lanes always exist in a network setting, as they are connected to other roads. Designating a HOT lane can cause travellers to change their routing on this larger network, potentially causing congestion on other parts of the network, including at points of entry to and exit from HOT lanes. Such congestion can be taken into account using models of network level congestion. Using such modelling techniques can improve the ability to quantify the net benefits and welfare effects of HOT lanes. Such modelling can play an important role in studying where HOT lanes should be designated and what kind of pricing should be used both on and off the HOT lanes.

Acceptability

Public and business support for congestion charging proposals tend to follow the pattern identified by Goodwin a decade ago (Figure 3). Support can be low at the critical point of introduction, but will tend to increase subsequently as the concrete benefits become evident. This pattern was observed in Stockholm, where the congestion charging scheme was endorsed via a positive result in a referendum held seven months after its introduction (Borjesson et al., 2015). The pattern may be particularly apparent when there is no trial period for users to experience the impacts of the system.

Policy makers should pay careful attention to the system design elements that most affect acceptability. This section highlights several factors that may contribute to improved acceptability, including the provision of consumer choice, the presentation of the charge as a value proposition rather than a tax, the hypothecation of revenues to specific purposes, the nature of the pricing model adopted and the integration of congestion charging into a wider Sustainable Urban Mobility Plan (SUMP).

Figure 3. Evolution of public support for congestion charging over time



Source: Goodwin, P., in ITF (2010).

The importance of choice

The acceptability of congestion charges appears to be much improved where road users can choose whether they pay the charge. This issue of choice has at least two dimensions. First, it refers to the ability to make the journey by private car without incurring the charge. The HOT lane context is the one in which the choice is clearest, since general purpose lanes run parallel to the HOT lane, providing a direct substitute for the paid journey, which differs only in terms of the level of congestion encountered. However, choice also exists if there are feasible alternative arterial roads that can reasonably be used to complete the journey. The ability to exercise choice may be further enhanced over longer routes where pricing is segmented and consumers can move into and out of the HOT lane.

The second dimension to choice is the option to use an alternative mode of travel. That is, the question of whether there are feasible (in terms of time, convenience, etc.) options to complete the journey via public or active transport, carpooling, etc. It is this dimension of choice that is relevant in the context of cordon-charging, as distinct from route charging. Thus, congestion charging proposals are typically presented as part of a package which includes improvements to other transport options. The Israeli HOT lane experience, discussed above, provides an example of this dynamic, with a new, free "park-and-ride" shuttle bus service being integrated with the HOT lane offer.

The importance of choice is demonstrated in part by the results of research on usage patterns in HOT lanes, which indicates that the majority of users make infrequent trips on the tolled lanes, presumably doing so when they have a particularly high VOTT due to specific appointments or other urgent needs.

Presentation

Another perspective is that the ability to choose between a tolled HOT lane and a parallel general purpose lane allows the toll to be presented as a positive choice, rather than the imposition of a tax. In the United States, the tolls on HOT lane users are typically referred to in terms of value pricing. This is based on the notion that the price paid represents the purchase of a journey time saving, or avoidance of congestion, rather than a tax paid as a result of the user imposing a negative externality. This rhetorical shift seems to have been associated with a significant improvement in acceptability: Poole (2020) notes that "HOT lanes grew rapidly when the [US] federal government shifted rhetorically from congestion pricing to value pricing". That said, increasing practical experience with the use of HOT lanes may also be a key factor in enhancing their acceptability.

Hypothecation of revenue

Hypothecation of the revenue derived, typically to fund other transport projects, is a common feature of congestion charging schemes and is frequently seen as a necessary means of enhancing public acceptability. For example, a 2006 survey of London businesses found that support for the congestion charge was contingent on the revenues being hypothecated to transport and access projects within the Greater London area.[17] In practice, a large majority of the net revenue from the London Congestion Charge has been used to improve the bus network, with funds also being allocated to improving roads and bridges, road safety initiatives, financing local transport/borough plans for sustainable mobility and the environment.[18] The congestion charging proposals developed in Bogotá in recent years also included hypothecation of all revenues to public transport improvements (Bocarejo, 2020). The Manhattan congestion charging scheme expected to be adopted shortly will see revenues directed to public transport improvement projects, particularly for the subway, and is expected to fund around 30% of the Metropolitan Transportation Authority's five-year capital budget (Curbed New York, 2020).

As in the London case, a key rationale for hypothecating the revenue from the congestion charge is likely to be concern to ensure that adequate choices are available to travellers following the introduction of the congestion charge. This may imply improving the quality of public and active transport services to make them a more feasible alternative to private vehicle use for a wider range of journeys, as well as increasing public transport capacity to accommodate expected modal shift.

Hypothecation does not necessarily have to be closely or even logically related to the amelioration of problems faced by users wanting to avoid tolls. In some cases, the key benefit of hypothecation is simply that citizens are assured that something of value, usually within the transport sector, will be obtained as a result of the charges. For example, when Oslo introduced a cordon charge for entry to its city centre, the revenues were used to build an underground express bypass of the city centre, which was popular among users for its convenience and among city residents for its environmental benefits in diverting city street traffic (Gomez-Ibañez and Small, 1994).

Hypothecation may also be adopted to address concerns that the imposition of a congestion charge has been motivated more by a desire to generate a new form of tax revenue than as a means of addressing negative externalities. Being able to link the tax revenue collected with the provision of specific services may help allay public distrust, while hypothecating the revenue to other transport projects provides a clear link between payers and beneficiaries, in that both groups are transport users. Both dynamics are likely to improve the public acceptability of congestion charging. Nevertheless, increases in congestion charges are still susceptible to being regarded as being motivated by desire to expand tax revenue when they are not linked to regular review of traffic flow, traffic speeds or congestion levels.

Hypothecation can also present risks. In particular, it can lead to substantial revenues being directed to specific uses that, over the longer term, prove to be inefficient or ill-adapted to emerging priorities. In such cases, the ability to redirect revenues to better uses can be constrained, even in the medium term, by the public commitments that have been made to use revenue for particular purposes. This suggests the need to avoid framing commitments to hypothecate revenue in unduly specific ways and the potential benefit of scheduling a review of the results of programmes to which the revenues have been directed.

Other fiscal options may also be available to address acceptability. Taking a revenue-neutral approach, by reducing other taxes, is one possibility if it is compatible with preserving incentives for efficiency. The Singaporean approach, noted above, of presenting road user charging as a mechanism to enable reductions in the high vehicle ownership taxes, and thus expand vehicle ownership, is an example of this (Theseira, 2020). This was part of an overall policy of improving the targeting of incentives, shifting away from constraining car *ownership* towards constraining car *use*, by moderating but not removing the steering effect of ownership taxes. When the ERP system was introduced, the government both lowered the initial charges below those of the predecessor ALS (which it could do efficiently because the marginal ERP charge could be lower than the fixed ALS charge, yet have the same effect) and also lowered and restructured other vehicle taxes, to demonstrate that the policy intent was to improve road charging efficiency rather than increase revenue.

Where differentiation of existing taxes on cars is used to create incentives for cleaner vehicles, care must be taken not to lose this steering effect, and this may rule out the adoption of a revenue-neutral approach (OECD, 2019). When road pricing is restricted to small parts of the overall road network the asymmetry makes off-setting reductions in other vehicle taxes unlikely to be useful. The constituency affected by congestion charges will be very much smaller than that affected by changes to ownership charges. The change in ownership charges will be too small for the consumer to notice if neutrality applies to treasury revenue. Singapore's congestion charges apply to a very large part of its overall road network.

An overly-comprehensive approach to revenue neutrality can also be counterproductive for system-wide road pricing. For example, it may have contributed to the abandonment of a proposal to introduce differentiated electronic vehicle kilometre charges for all vehicles across the Dutch road network. The new charge enjoyed general public support following thorough consultation via a stakeholder platform and was approved by the cabinet in 2009. However, proposals to modify every other tax related to vehicle ownership and use generated opposition on too many fronts to be manageable (Oosterhuis and Brink, 2014).

There is no clearly preferred approach to the hypothecation issue. The most appropriate use of the revenues generated by congestion charging is likely to vary with the circumstances of different cities and countries and the policies of politicians controlling different levels of government and different jurisdictions in the city and its surrounding region. All of these circumstances may vary over time.

Pricing models and equity

There have long been concerns over the equity impacts of congestion charging, albeit that most studies of the overall distributional impact of road pricing find that it is small (ITF, 2018). In this context, the increasingly clear evidence that a wide range of income groups choose to pay congestion charges (and thus reap welfare benefits) in the HOT lane context (e.g. Hall, 2020a) helps demonstrate that speed and reliability are greatly valued in some circumstances even by people on low-incomes.

The specific pricing model adopted is important in determining the size of the equity effects that result. The ITF has previously argued that differentiating charges by time and location, according to the distribution of congestion, will always reduce distributional impacts. Conversely, while exemptions and discounts have been widely adopted as means of addressing equity concerns, there are significant risks in terms of both their vulnerability to fraud and, most importantly, their ability ultimately to jeopardise the effectiveness of the road pricing scheme in managing congestion (ITF 2018).

The Roundtable noted that, in a small number of US HOT lanes, members of lower income groups pay tolls at concessional rates and considered that there is likely to be potential to use this approach to address some equity concerns and thereby improve the acceptability of congestion charging.

Congestion charging as part of an integrated urban mobility plan

While congestion charging's specific rationale is grounded in the potential to improve welfare by internalising the external costs of congestion, the broader context is one in which governments are increasingly adopting integrated policies such as Sustainable Urban Mobility Plans (SUMPs). These seek to enhance urban quality of life by implementing a co-ordinated set of transport and land use planning policies which take into account a broad range of public policy objectives and impacts of transport choices, including health, noise, air pollution and other urban amenity values. SUMPs generally envisage modal shifts away from private vehicle use towards public and active transport, including shared and micromobility services, through a range of mutually-supportive policies. Congestion charging proposals clearly need to be an integrated part of SUMPs where the latter exist. SUMPs are subject to regular review and public approval, not least through local elections, and developing congestion charging proposals in this context has the potential to increase acceptability.

Within Europe, there is an increasing move to adopt SUMPs as the basis for urban mobility policies. SUMPs were first introduced as a local planning tool in France by a national transport law (Loi d'orientation sur les transports intérieurs) in 1982 and made obligatory for cities over 100 000 in 1996. Central funding of transport investments is contingent on adoption of a SUMP. The SUMP concept was adopted for Europe more broadly as part of the European Commission's 2013 Urban Mobility Package. The European Commission (EC) "strongly recommends that European cities and towns of all sizes should embrace its concept of Sustainable Urban Mobility Plans", which have as their central goal "…improving accessibility of urban areas and providing high-quality and sustainable mobility and transport to, through and within the urban area. [The SUMP]… regards the needs of the 'functioning city' and its hinterland rather than a municipal administrative region." (European Commission, 2013).

The EC promotes SUMPs as being capable of greatly improving the overall quality of life of urban residents by addressing issues including congestion, air and noise pollution, climate change, road safety, liveability and the integration of new mobility services into the transport system[19]. The SUMP concept thus reflects the increasing focus of policy makers on the concept of the liveability of cities. Similarly, Singapore has for some years published "Land Transport Master Plans" which embody many of the principles found in SUMPs, such as implementing co-ordinated transport and land use policy (in conjunction with land-use master planning) to deliver sustainable urban mobility. While formal planning tools equivalent to the SUMP do not seem to have been adopted widely to date beyond Europe, the key policy concerns and instruments which they contain are widely adopted in urban policy analysis and practice.

In this context, congestion charging can be seen as one of a suite of mutually supportive policies, which are discussed in the following sections. This approach will maximise the effectiveness of decongestion charges and may have the potential to significantly enhance the political acceptability of congestion pricing.

Links between decongestion charges and other policies

Several alternative policy tools for addressing the demand for scarce road space have been developed. These include managing the supply and price of parking in urban centres, applying selective access restrictions (typically based on licence plate numbers), road space reallocation and initiatives to improve and expand the supply of public transport. In some cases, one or more of these policies have been implemented in response to the political difficulties expected to be encountered with a congestion charge. In others, they have been adopted as complementary policies. Road pricing also has significant links to plans for increasing road capacity and to the pricing of public transport.

Congestion charging and road capacity expansion

The potential adoption of decongestion charges may have important implications for decisions regarding investment in road capacity expansion. For example, some potential road investments may be considered uneconomical if the level of induced demand is such that it is expected to undermine the potential benefits within a short period. However, in some cases, if congestion charges are imposed to limit the extent of this induced demand, the investments could become worthwhile. Conversely, it is possible that investments in increased road capacity may no longer be warranted in some circumstances if pricing sufficiently limits congestion. This highlights the importance of integrated decision-making in road traffic management.

Congestion pricing and public transport policies

Congestion charging is typically expected to lead to modal shift away from private vehicle use, as well as shifting departure times to smooth demand for access to congested roads. This is often reflected in the simultaneous adoption of policies to expand and improve public transport services. As discussed above, the Israeli HOT lane initiative has explicitly incorporated the provision of new, high-quality public transport services into the contracting arrangements governing the provision of a new HOT lane facility built via a PPP. This appears to have been successful in driving a marked increase in the mode share of public transport on this route.

The Roundtable participants did not reach a conclusion regarding when the adoption of congestion pricing promotes the use of public transit and to what extent. However, it necessarily provides some incentive for car users to change modes, by increasing the relative cost of using private vehicles during congested periods. Any bus or tram service sharing congested roadways will also benefit as those streets become less congested. To this extent, public transport service quality is increased via shorter journey times and, most likely, journey-time reliability improvements, due to the introduction of congestion charging even if no new expenditures on transit are adopted as part of the policy.

The interactions between road pricing and policy towards provision and pricing of public transit are complex. Proost (2018) notes that low public transport prices have typically been promoted as a second-best form of pricing; that is, because the price of private vehicle travel is sub-optimally low due to unpriced congestion, pollution and other externalities, lowering the price of the substitute is likely to lead to welfare gains. Proost argues that, if road pricing initiatives internalise the externality costs, it may no longer be necessary to price public transport below marginal cost: “The theoretical principles are clear: in the absence of road pricing, pricing public transport below its marginal cost is a sensible second-best strategy. But when road pricing is introduced, it is optimal to also charge the full marginal social cost for public transport” (Proost 2018).

Pricing transit at marginal cost strengthens the case for public transit to make use of peak-load pricing, as is currently done in some cities including London and Washington DC. Proost’s modelling, based on simulations for Stockholm, with its congestion charging system in place, shows that welfare improvements can be obtained by differentiating public transport prices across peak and non-peak periods and increasing fares in the peak periods. He notes that this issue has significant importance in the context of densely-populated cities in which public transport typically has a higher modal share than private transport in the congested urban centres during peak periods. In these circumstances, *“*Correcting prices for the small share of road users and forgetting to correct pricing for the majority of commuters that use public transport would be a mistake.”

However, there is an evident risk that adopting significant increases in peak period public transport prices in tandem with the introduction of congestion charging could undermine public support for the congestion charging initiative. This risk might potentially be mitigated by presenting the fare increase as the mechanism by which increased peak hour services are to be (at least partially) funded, so that a value proposition is put forward.

Where it is considered politically infeasible to increase peak hour public transport prices, an alternative, albeit less effective, approach is to differentiate public transport prices by lowering off-peak fares. This will only be appropriate in circumstances in which fare revenue covers a substantial part of the operational cost of public transport services. Off-peak discounts are used in Singapore and Hong Kong, China.[20] In both cities public transit systems are notable for the large fraction of operating costs covered from fare revenues. Another example of this approach is the recently announced move to reduce off-peak public transport fares by 30% in Victoria, Australia for a trial period.[21] There is some theoretical support for this approach in analyses showing that public transport involves strong economies of scale (Mohring, 1972; Parry and Small, 2009).

Parking management

As most journeys end with the vehicle being parked at the destination, policies that affect the supply and price of parking can potentially have substantial impacts on travel choices and, hence, on congestion. The ability to vary parking charges with both time and location mean that these charges can influence many of the traveller decisions that a congestion toll would affect (Hall, 2020b). One exception is that parking management policies do not affect route choice, while another is that they do not affect vehicles that drop passengers off without parking, including taxis, ridesourcing services and perhaps autonomous vehicles in the future.

City centre parking management policies are typically cheaper to adapt than developing a tolling system. They are often not as politically difficult to implement, although significant reductions in parking in major retail locations can be controversial, due to concerns over the effect of such changes on accessibility for customers, and hence on business activity levels.

Parking policies across the metropolitan area significantly influence car use. Parking itself is responsible for the consumption of vast amounts of land, accounting for a substantial share of the social costs of car ownership and use (Franco, 2020). In many cities, outdated regulations mandating the number of parking spaces that must be included in a development have encouraged a general oversupply of both on-street and off-street parking, indirectly subsidising car use, increasing property prices and driving sprawl. These planning guidelines, together with zoning regulations on the density of development need to be made consistent with transport interventions to regulate car use and address congestion (ITF, 2021).

Licence plate-based access restrictions

Some cities have adopted schemes that effectively ration access to the central area on a daily basis, using the vehicle licence plate to determine which vehicles have access on which days. This mechanism was originally conceived to address transient peaks in air pollution levels due to atmospheric conditions, but is now also seen as a congestion control measure in some cities, for example Bogotá. Schemes differ in the extent of the restriction imposed; Bogotá only allows vehicles to be used on alternate days (cars with plates ending in odd numbers are subject to restrictions on odd numbered days of the month, and vice versa.

This approach has a number of weaknesses. It is a blunt instrument, with little ability to fine-tune the number of vehicles entering the centre. It may also increase multi-car ownership in households that can afford it, as a means of ensuring access to the centre on all days; this greatly limits the effectiveness of the mechanism as a congestion control, and may even make congestion worse if the second car results in new trips. Furthermore, it leads to underutilised assets, which is an economic burden. It can also have the perverse effect of increasing air pollution, to the extent that people substitute older and less well-maintained second cars for their primary vehicle in order to maintain daily access to the centre.

Bogotá has recently responded to this dynamic by adding an option to purchase an exemption from the licence plate-based restrictions as a new feature of its scheme. This is intended to reduce the incentive to purchase more vehicles.

Vehicle permits

Several cities, including Singapore and Beijing, limit the number of vehicles in the city by requiring residents to obtain a permit to own a vehicle. Limiting the number of permits can limit congestion. However, as Hall (2020b) notes, this is also a “blunt instrument”, which may result in limited, or even negative, welfare gains. One important factor in determining their welfare impact is the means of allocating permits. This may be done by lottery or auction. An auction-based system will typically yield better welfare outcomes by allocating permits to those who value them most highly. Conversely, such allocation arrangements may raise equity concerns, particularly if low permit numbers lead to very high auction prices. Tokyo and some other Japanese cities restrict car ownership by requiring proof of ownership or lease of off-street parking space.

Distance-based charging

Distance-based road user charging is increasingly regarded as a preferred means of ensuring that road users contribute efficiently and equitably to the costs of their road usage. It also has the potential to incentivise more productive development of urban space, containing the space devoted to roads (Crozet and Mercier, 2017). Per kilometre charging, unlike vehicle ownership charges, ensures that the amounts paid by individual motorists are proportionate to their use of the road system (and hence the costs that their use imposes). Distance-based charges are increasingly seen as preferable to widely used fuel taxes, on similar grounds. While fuel taxes have historically been favoured as providing a strong link between usage and taxes paid, this link will increasingly be weakened as the market penetration of electric vehicles in the vehicle fleet continues to increase. As the electricity that fuels vehicles cannot readily be taxed in the same way as petrol or diesel, continued reliance on fuel taxes would result in an increasingly large cohort of drivers making much smaller contributions to the costs of the road system.

However, it is important to distinguish between the two objectives of internalising the general costs of road usage (which include maintenance costs and pollution and crash costs) from the specific case of congestion costs. This is because, while the general costs of road usage are broadly proportionate to the distance travelled, the costs of congestion arise only in specific contexts of place and time. This fundamental difference in the incidence of these costs suggests that, where distance-based charging is adopted, a two-tier charging structure is likely to be needed, with congestion-based premiums being added to a broader average cost distance-based charging regimen, with charges differentiated by time and location.

Road space reallocation

Road space reallocation involves taking road space currently devoted to car traffic or parking and designating it instead to other purposes.[22] Those purposes could be to accommodate high-occupancy vehicles (HOV or HOT lanes), other travel modes (bus lanes, rail or light rail lines, bike lanes, footpaths) or non-transport uses such as public meeting space and sidewalk businesses.

Road space reallocation may relieve congestion by encouraging modal switching towards public and active transport modes, which are less space-intensive. Because the immediate impact is to reduce the road space available to low-occupancy cars, it can exacerbate congestion in the short term, although as noted earlier a reversal of traffic induction will mitigate this effect and the result may be a reduction in congestion (ITF, 2021). The longer-term outcome is also dependent on a wide variety of behavioural responses, including mode of travel, car ownership, home and job location, and urban development investments.

Road space reallocation policies are increasingly widely implemented in dense urban areas even though, in common with congestion charging, schemes frequently face substantial opposition from local groups.

Improving active transport

Investment in improving active transport infrastructure (e.g. by building bicycle lane networks and pedestrianising inner urban areas) can help reduce congestion by providing more attractive alternatives to private vehicle use. Improving pedestrian infrastructure can also improve access to public transport networks, and integrating cycling infrastructure and shared micromobility parking with public transport can extend the reach of bus, metro and rail systems. As discussed in some detail above, proposals to invest in these mobility options in conjunction with congestion charging may make proposals more politically viable. Even if the direct impact of investment in active transport on congestion is not very large in the short run, it facilitates access and urban mobility without the need to own a private car, which might have a significant long-term impact on travel behaviour.

Looking towards the future

The case for congestion charging is theoretically well-established, and the relatively small number of schemes that have been adopted are generally considered to have been successful. The expected substitution of fuel taxes with vehicle kilometre charges will present opportunities for more use of congestion charging. In considering the potential future role of congestion charging, policy makers should also take account of a number of emerging trends which will also have a significant impact on the environment in which congestion charging schemes will operate, and should therefore be taken into account when planning new congestion charging initiatives.

HOT lanes as a transitional step towards full congestion charging

The Roundtable considered the question of whether HOT lanes might evolve towards network-wide congestion pricing. This arises naturally from the observation that the use of HOT lanes has grown relatively quickly in the United States in recent years. Poole (2020) suggests that it is feasible that HOT lanes could serve to generalise congestion charging, at least in the United States, perhaps with two-tier pricing as an intermediate step, entailing modest tolls applied to all lanes and value pricing applied as a premium to HOT lanes. He cites Fielding et al. (1993), which first coined the term "HOT lanes" as implicitly proposing this, given its subtitle "Phasing in congestion charging a lane at a time."

HOT lanes increasingly make use of real-time pricing, with users able to move in and out of the priced lanes as prices change. The limiting factor in how effectively HOT lane segments/routes can be linked into a network may be costly investments in interchanges, so that users don't have to exit HOT lanes to switch between facilities run by different operators.

Interconnection of HOT lanes might also result in toll rates becoming complex, making it more difficult for users to relate them to how much they are willing to pay to save time. A number of technology-based tools may be used to address this issue and improve the acceptability of real-time pricing in this context. For example, mobile phone apps could be developed which enable users to set their preferences, in a structured way, to guide decisions as travellers are updated with real-time tolling information. These could then calculate the actual and expected impact of real-time price changes on journey time and cost and advise the user on route choices that best meet their preferences. A further step down this path may be made with the adoption of autonomous vehicles, as discussed below.

The Israeli experience is relevant to the potential for value pricing to be adopted beyond HOT lanes themselves. The provision of additional transport options, in the form of a free park-and-ride shuttle bus service and free parking for carpool users, constitutes an important part of the value proposition for this facility and these additional modal choices appear to have been significant contributors to the overall impact in relieving congestion.

Autonomous vehicles

Widespread adoption of autonomous vehicles (AVs) will have a number of implications for congestion charging, both positive and negative. Automated communication between AVs has the potential to smooth traffic, reduce headways and reduce crash incidence, all of which are positive in relation to congestion. On the other hand, if AVs are affordable, automation could extend car ownership to a larger proportion of the population amongst the young, the elderly and those with disabilities, many of whom are unable to drive, whether due to legislative constraints or lack of personal capacities. This is likely to lead to significant rises in car trip frequency and vehicle kilometres travelled (Simoni et al., 2019). In addition, AVs can be expected to seek to avoid high inner urban parking costs by either circulating near their programmed pick-up point or travelling empty to a cheaper parking spot before returning to the city centre (Millard-Ball, 2019). This would add to congestion and at the same time reduce the effectiveness of parking management as a substitute policy for congestion charging. In addition, the VOTT of AV users is likely to be smaller than for other drivers, due to their ability to undertake other tasks while in the vehicle. This can be expected to increase the demand for private vehicle travel, potentially by significant amounts (Auld et al., 2017), and require much higher charges to effectively address congestion.

The likely net impact of AVs on congestion remains uncertain. Some observers believe that the reduced road capacity requirements for handling autonomous vehicles will more than offset induced travel, causing congestion to decrease (Winston and Karpilow, 2020). Other studies suggest that autonomous vehicles will be driven substantially more than comparable non-AVs, increasing congestion and potentially shifting the locus of congestion to new areas.

To the extent that the widespread use of AVs does increase congestion, the potential benefits of congestion charging are necessarily increased. Thus, AV adoption may become a significant force in making congestion charging more widespread. The expected reduction in the effectiveness of parking management as substitute policy will underline this effect. Furthermore, the greater opportunity to adopt more sophisticated toll-setting algorithms, linked to AV navigation systems, may enable congestion charging schemes to achieve better welfare outcomes. More generally, the fact that AVs already hold so much relevant information in digitised form, while some of it is already transmitted as part of vehicle guidance, suggests that congestion charging will be facilitated and implementation costs will fall.

The characteristics of AV behaviour may necessitate changes in the structure of congestion charging policies, if they are to continue to provide appropriate incentives. For example, Millard-Ball (2019) argues that the incentive for AVs to cruise in inner-urban areas, and the consequent blurring of the boundaries between parking and travel, will require new pricing strategies. A two-part pricing strategy could include a time-based charge for occupying the public right-of-way, whether parked or in motion, and a distance- or energy-based charge that internalises other externalities from driving.

Conclusions and recommendations

Conclusions

Congestion is a problem in many cities. Effective traffic management requires integrated transport and land use policies and a suite of measures to incentivise efficient use of roads and scarce urban space more broadly, including charges for parking. Charging for road use can be particularly effective but, some 45 years after Singapore first adopted a cordon-based congestion charging scheme and almost 20 years after London's Congestion Charge was implemented, such schemes remain rare. Achieving public acceptability for road pricing proposals is challenging, despite the well-documented success of the schemes operating in cities including Singapore, London and Stockholm and clear theoretical foundations for this policy tool.

In this context, the experience with HOT lanes may provide important lessons. The use of HOT lanes has developed relatively rapidly, with 52 projects having been brought into operation in the United States in the 25 years since they were first deployed. Rapid adoption has probably been facilitated by the voluntary nature of the charge, with drivers able to choose to use toll-free general purpose lanes running parallel to the HOT lane. Adoption was also facilitated by the fact that many HOT lanes were implemented simultaneously with building new capacity, so that few if any users actually experienced a reduction in the choices open to them. Successful implementation of dynamic pricing to achieve throughput targets has been demonstrated and early concerns regarding equity impacts have proven to be largely unfounded, with users spanning a wide range of income groups.

While the development of HOT lanes has occurred mainly in the United States, the experience of Israel in operating a successful HOT lane since 2011 provides a practical demonstration of the use of HOT lanes in a quite different context. The Israeli experience also demonstrates the potential for HOT lanes to be used in conjunction with extending travel options, including a free park-and-ride express bus system and a free parking and carpooling option.

The experience with HOT lanes suggests that they will continue to be added to the highway network, making congestion charging more widespread. This may make more general use of road pricing acceptable by enhancing familiarity with road user charging over time and demonstrating the user benefits.

While the use of congestion charging has expanded quite slowly to date, new impetus seems to have developed in recent years, with schemes having been adopted (Bogotá and Milan), being close to adoption (New York City) and under active consideration (Vancouver).[23] In the short to medium term, traffic pressures due to the possible reluctance of commuters to return to the public transit system in the post-Covid-19 context, may result in development of proposals for more congestion charging schemes. New congestion charging schemes will benefit from lessons arising from the use of congestion charging to date, on which the following recommendations are based.

Recommendations

Ensure adequate user choice to accommodate responses to congestion charging

The behavioural changes prompted by congestion charging necessarily have implications for other areas of transport policy. These should be analysed in the specific context and necessary policy changes made at the outset as part of an integrated approach. Decongesting roads through congestion pricing will improve the speed and reliability of bus services, enhancing this alternative to car use. The provision of more and better public transport services and the facilitation of active transport through provision of appropriate infrastructure widens choice. When designing congestion charging and related policies, policy makers should take account of experience showing that people adapt to road pricing via a wide range of behaviour changes.

Ensure congestion charging revenues are used effectively and with public support

The purposes to which congestion charging revenues are directed are critical to the overall welfare impact of the policy. They are also central to the political viability of the policy and they greatly influence the level of public support. Beneficial uses depend on local circumstances, but might include transport infrastructure and rolling stock investments, subsidies to public transport or compensating reductions in transport-sector taxes. Revenues should be directed to investments and expenditures that have been prioritised by economic appraisal and public consultation. It is critical that the public understand and accept the merits of the revenue uses that are chosen.

Hypothecate revenues flexibly to identified priorities for sustainable mobility

Expanding transport choices is likely to require substantial investments in public and active transport. There will be large benefits if projects are well chosen. Congestion charging revenue provides a potentially major revenue source, and explicitly hypothecating this revenue to such projects can help win public acceptance. In some cases there may also be a good case for using the revenue to improve parts of the road network. However, hypothecating revenues risks locking in expenditures on projects or project types that over time deliver diminishing value for money, perhaps due to unanticipated issues or to changes in travel behaviours or other factors. These risks are likely to grow with time as circumstances change. The longer revenue uses are constrained by legislation or legal contract, the more chance that they eventually produce unsatisfactory results. If congestion charging revenue is hypothecated, it should be to expenditure on sustainable mobility options, retaining flexibility to modify allocation as priorities evolve.

Use differentiated congestion charges to maximise benefits and minimise costs

Using differentiated pricing allows roads to be used at lower or zero cost outside peak periods. This can help to minimise negative public perceptions of congestion charging policies and ensure that assets are not underutilised outside peak periods.

Present congestion charging as value pricing or decongestion charging

Decongestion charging or value pricing is a more positive and appropriate way to characterise congestion charges than as an additional tax. The experience with HOT lanes strongly suggests that users are more willing to pay congestion charges when these are presented as a price paid in exchange for a valuable benefit (i.e. travel time savings), rather than as a tax or penalty. Careful presentation of the nature and purpose of congestion charges is potentially a key factor in successfully implementing a scheme.

Make more use of HOT lanes and peak pricing on tolled expressways

In principle, HOT lanes are less efficient than pricing congestion on all lanes of a highway or all of the road network. In practice, HOT lanes have proved a successful tool as part of strategies to manage traffic. They have become important components of investment in new highway capacity in the United States, and have been successfully integrated with express bus services and a park-and-ride facility in Israel. Deployment in other countries is likely to be beneficial. More generally, opportunities to differentiate charges on tolled urban highways in response to congestion should be exploited. The government of Chile's initiative of modifying the concession for the urban expressway in Santiago to introduce peak pricing provides one successful example.

Consider possibilities for reform of public transport pricing

In cities where public transport already has a large modal share during peak travel periods, congestion pricing runs the risk of exacerbating overcrowding on public transport during those periods. While increasing capacity is one possible response, a more efficient response may sometimes be to differentiate pricing between peak and non-peak periods, as is done currently in some cities, including London and Washington DC. This provides incentives to shift public transport trips away from the peak, which can yield significant cost savings to the operator and reduce crowding and delays. One option may be to use some congestion charging revenues to lower average fares at the same time as raising peak public transit fares. With or without road pricing, peak pricing in crowded public transport systems will bring benefits.

Consider congestion charging as part of sustainable urban mobility plans

Cities, particularly in Europe, are increasingly adopting broad policy packages such as Sustainable Urban Mobility Plans (SUMPs), which seek to ensure improved accessibility and mobility as a key element of more liveable cities. Decongestion charging should be considered for inclusion in SUMPs and charging proposals are likely to be more successful if adopted as part of such an integrated package. SUMPs typically include a range of measures aimed at changing mobility habits, including encouraging modal shift to public and active modes of transport, favouring shared mobility and addressing accessibility issues through land use changes, virtual alternatives and other approaches. Where SUMPs exist, congestion charging proposals must clearly be an integral part of planning. Cities without SUMPs will find it useful to develop them in order to frame congestion and traffic management policies.

Notes

1 Vehicles parked in public spaces within the cordoned area during the relevant peak periods are also charged, regardless of whether they are driven.

2 However, the New York State government has approved the application of such a charge in New York City. Implementation was scheduled for January 2021, although Federal government environmental approval requirements have led to delays. [https://ny.curbed.com/2020/7/15/21324020/congestion-pricing-delayed-mta-cars-slow-new-york-city] HOT lanes are widely adopted as an alternative policy instrument, as discussed below.

3 For example, within a few years of London's congestion charge being introduced in 2003, congestion had been reduced by 30%, there were significant improvements in bus reliability and journey times, negative impacts on the central London economy were found to be marginal and annual net revenues of around £90 million were being generated (Transport for London, 2005) "Central London Congestion Charging: Impacts Monitoring, Third Annual Report").

4 https://www.theguardian.com/politics/2008/dec/12/congestioncharging-transport.

5 But a 2019 report indicated that similar proposals were again under consideration. https://www.bbc.com/news/uk-scotland-edinburgh-east-fife-48328062.

6 Based on TfL Statements of Accounts, cited here: https://theconversation.com/london-congestion-charge-what-worked-what-didnt-what-next-92478.

7 https://www.legislation.gov.uk/ukpga/1999/29/section/295.

8 Though the qualifying criteria have in most cases become more stringent, effectively limiting the number of vehicles that are able to use HOT lanes on a toll-free basis.

9 One argument in favour of discounts is that they may help to overcome the costs of organising carpools which may entail a type of market (or coordination) failure. Carpool organisation costs are featured in: Konishi, Hideo and Se-il Mun (2010), "Carpooling and Congestion Pricing: HOV and HOT Lanes", Regional Science and Urban Economics 40(4), 173-186.

10 The operator receives ILS 10 per car parked in the carpark, plus a toll equivalent payment for each HOV using the HOT lane toll-free and for each "authorized vehicle".

11 Poole cites Polzin (2013) as reporting that, from 1980 to 2010, carpooling declined from 19.7% of commuters to 9.7%, while Aevas (2019) found that it had declined further to 9.0% by 2018.

12 In 2016, a two-phase HOT lane pilot project was launched in the Greater Toronto and Hamilton Area (https://www.ontario.ca/page/high-occupancy-toll-hot-lanes). Phase 1 entailed conversion of a HOV lane to HOT in each direction on a 16.5 km stretch of the Queen Elizabeth Way. HOV2+ and vehicles with green license plates (i.e. plug-in hybrid electric vehicles and battery electric vehicles) remain free. Single Occupancy Vehicles can access the HOT lane using permits. The number and price of permits is subject to change. Phase 2 of the project, scheduled to begin in 2021, involves building new HOT lanes on a 15.5 km stretch of Highway 427 with Electronic Toll Collection used. The project falls short of true congestion pricing since users of the HOT lane buy 3-month permits, rather than paying per trip.

13 The fee was SGD 3 on introduction in 1975, rose to SGD 4 in 1976 and to SGD 5 in 1980, before being reduced to SGD 3 in 1989 and SGD 2 in 1994. The ALS was replaced in 1998. See Foo (1997).

14 A low coefficient of variation (below 40%) was found to be associated with a benefit outcome closer to the ideal toll, while greater variation was associated with an outcome closer to that of the fixed toll.

15 https://www.itsinternational.com/its1/feature/pricing-practise-hot-lane-operation.

16 1 bus = 1.6 passenger car equivalents.

17 https://publications.parliament.uk/pa/cm200607/cmselect/cmtran/692/692w1e09.htm.

18 https://tfl.gov.uk/corporate/transparency/freedom-of-information/foi-request-detail?referenceId=FOI-2271-1617#:~:text=All%20revenue%20generated%20by%20the,in%20the%20Capital's%20transport%20infrastructure.

19 https://ec.europa.eu/transport/themes/urban/urban-mobility/urban-mobility-actions/sustainable-urban_en.

20 See: https://www.ptc.gov.sg/fare-regulation/bus-rail/morning-pre-peak-fares; and https://www.researchgate.net/publication/311628875_Reducing_Subway_Crowding_Analysis_of_an_Off-Peak_Discount_Experiment_in_Hong_Kong.

21 https://www.ptv.vic.gov.au/news-and-events/news/2020/12/01/off-peak-fare-discount-on-public-transport/.

22 For a comprehensive list of road space reallocation options, see: https://www.vtpi.org/tdm/tdm56.htm.

23 See: Toronto Star (2020), "Vancouver is the first Canadian city to pursue a congestion charge. Is Toronto next? 22 November 2020. https://www.thestar.com/news/canada/2020/11/22/vancouver-is-the-first-canadian-city-to-pursue-a-congestion-charge-is-toronto-next.html.

References

AHB35 (2019), Managed lanes database. https://managedlanes.wordpress.com/2017/07/07/projects-database/ (retrieved 14 May 2020).

Altshuler, A. (2010), "Equity, Pricing, and Surface Transportation Politics", *Urban Affairs Review*, Vol. 46/2, pp. 155-179, https://doi.org/10.1177/1078087410378487.

Anas, A. and T. Hiramatsu (2013), "The Economics of Cordon Tolling: General Equilibrium and Welfare analysis", *Economics of Transportation*, 2013, Vol. 2/1, pp. 18-37, https://doi.org/10.1016/j.ecotra.2012.08.002.

Auld, Joshua, V. Sokolov and T. S. Stephens (2017), "Analysis of the effects of connected-automated vehicle technologies on travel demand," *Transportation Research Record: Journal of the Transportation Research Board*, 2615: 1-8, https://doi.org/10.3141/2625-01.

Bento, A., K. Roth and A. Waxman (2020), "Avoiding Traffic Congestion Externalities? The Value of Urgency", *National Bureau of Economic Research Working Paper,* https://www.nber.org/papers/w26956.

Bocarejo, J.P. (2020), "Congestion in Latin American Cities: Innovative approaches for a critical situation". *International Transport Forum Discussion Papers*, No. 2020/06, OECD Publishing, Paris, https://doi.org/10.1787/938de08e-en.

Börjesson, M. (2017), Long-term Effects of the Swedish Congestion Charges, presentation by Maria Börjesson, Swedish National Road and Transport Research Institute (VTI), https://www.itf-oecd.org/long-term-effects-swedish-congestion-charges.

Börjesson, M. et al.(2015), "Factors driving public support for road congestion reduction policies: Congestion charging, free public transport and more roads in Stockholm, Helsinki and Lyon". *Transportation Research*, Part A, 78 (2015), 452 – 462, http://dx.doi.org/10.1016/j.tra.2015.06.008.

Brent, D.A. and A. Gross (2017), "Dynamic road pricing and the value of time and reliability", *Journal of Regional Science*, Vol. 58, No. 2, pp 330-349, https://doi.org/10.1111/jors.12362.

Carey, M. and A. Srinivasan (1993), "Externalities, average and marginal costs, and tolls on congested networks with time-varying flows", *Operations Research*, 41(1), 217-231, https://doi.org/10.1287/opre.41.1.217.

CEBR (2014), "The future economic and environmental costs of gridlock in 2030", Centre for Economics and Business Research, https://www.ibtta.org/sites/default/files/documents/MAF/Costs-of-Congestion-INRIX-Cebr-Report%20%283%29.pdf.

Cohen-Blankshtain, G., H. Bar-Gera and Y. Shiftan (2020), "Congestion Pricing with Minimal Public Opposition: The Use of High-occupancy Toll Lanes and Positive Incentives in Israel", *International Transport Forum Discussion Papers*, No. 2020/09, OECD Publishing, Paris, https://doi.org/10.1787/ead92f06-en.

Crozet, Y. and A. Mercier (2018), "Urban Toll: Rethinking Acceptability through Accessibility", *International Transport Forum Discussion Papers*, No. 2018/16, OECD Publishing, Paris https://doi.org/10.1787/af22477a-en.

Curbed New York (2020), "Congestion pricing delayed as new car owners threaten to slow New York to a crawl", https://ny.curbed.com/2020/7/15/21324020/congestion-pricing-delayed-mta-cars-slow-new-york-city

European Commission (2013), "A concept for sustainable urban mobility plans", COM (2013) 913 final. https://eur-lex.europa.eu/resource.html?uri=cellar:82155e82-67ca-11e3-a7e4-01aa75ed71a1.0011.02/DOC_4&format=PDF.

FHWA (2020), List of National Specialty Lanes (draft), Federal Highway Administration Research and Technology, Autumn 2020.

Fielding, G. et al. (1993), "High Occupancy Toll Lanes: Phasing in Congestion Pricing a Lane at a Time," Reason Foundation, https://reason.org/wpcontent/uploads/files/22b593c21e642143157e65dc5223ce9a.pdf.

Fleming, T., S. Turner and L. Tarjomi (2013), "Reallocation of road space", New Zealand Transport Agency research report 530, https://www.researchgate.net/publication/335210756_Reallocation_of_road_space/link/5d5742a9a6fdccb7dc427186/download.

Foo, T.S. (1997), "An effective demand management instrument in urban transport: the Area Licensing Scheme in Singapore", *Cities*, Vol. 14, Issue 3, https://doi.org/10.1016/S0264-2751(97)00055-3.

Franco S. (2020), "Parking Prices and Availability, Mode Choice and Urban Form", *International Transport Forum Discussion Papers*, No. 2020/03, OECD Publishing, Paris, https://doi.org/10.1787/04ae37c3-en.

Gardner, L.M. et al. (2014), "Robust tolling schemes for high occupancy/toll (HOT) facilities under variable demand", *Transportation Research Record*, Vol. 2450, Issue 1, https://doi.org/10.3141/2450-19.

Gobierno del Colombia (2019), "Bases del Plan Nacional de Desarrollo" [Bases of the National Development Plan], Government of Colombia, https://colaboracion.dnp.gov.co/CDT/Prensa/BasesPND2018-2022n.pdf.

Gomez-Ibañez, J.A. and K.A. Small (1994), *Road Pricing for Congestion Management: A Survey of International Practice*, National Cooperative Highway Research Program Synthesis of Highway Practice No. 210, National Academy Press (1994).

Goodin, G. et al. (2011), "Operational performance management of priced facilities", report FHWA/TX-11/0-6396-1, http://tti.tamu.edu/documents/0-6396-1.pdf.

Hall, J. (2020a), "Can tolling help everyone? Estimating the aggregate and distributional consequences of congestion pricing", *Journal of the European Economic Association*, jvz082, https://doi.org/10.1093/jeea/jvz082.

Hall, J. (2020b), "High-occupancy Toll Lanes: Their Distributional Impact and Effect on Congestion", *International Transport Forum Discussion Papers*, No. 2020/07, OECD Publishing, Paris, https://doi.org/10.1787/04525828-en.

Hall, J. and I. Savage (2019), "Tolling roads to improve reliability", *Journal of Urban Economics*, Vol. 113, https://doi.org/10.1016/j.jue.2019.103187.

Hallenbeck, M. et al. (2019), "I-405 High Occupancy Toll Lanes Usage, Benefits, and Equity," University of Washington eScience Institute, www.depts.washington.edu/trac/bulkdisk/pdf/I-405ExpressTollLanesDSSGEquityFinal.pdf.

Ho, T.H., I.P.L Png and S. Reza (2017), "Sunk Cost Fallacy in Driving the World's Costliest Carsf". *Management Science*, Vol 64, No 4. https://pubsonline.informs.org/doi/10.1287/mnsc.2016.2651.

Independent (2013), "High Court rejects challenges to London congestion charges", 20 December 2013. https://www.independent.co.uk/news/uk/crime/high-court-rejects-challenge-to-london-congestion-charges-186684.html.

ITF (2021), "Reversing Car Dependency: Summary and Conclusions", *ITF Roundtable Reports*, No. 181, OECD Publishing, Paris, https://doi.org/10.1787/bebe3b6e-en.

ITF (2019a), "Regulating App-Based Mobility Services: Summary and Conclusions", *ITF Roundtable Reports*, No. 175, OECD Publishing, Paris, https://doi.org/10.1787/94d27a3a-en.

ITF (2019b), *Smart Use of Roads*, ITF Research Reports, OECD Publishing, Paris, https://doi.org/10.1787/42794582-en.

ITF (2018), "The Social Impacts of Road Pricing: Summary and Conclusions", *ITF Roundtable Reports*, No. 170, OECD Publishing, Paris, https://doi.org/10.1787/d6d56d2d-en.

ITF (2010), "Implementing Congestion Charging: Summary and Conclusions", *OECD/ITF Joint Transport Research Centre Discussion Papers*, No. 2010/12, OECD Publishing, Paris, https://www.itf-oecd.org/implementing-congestion-charges.

Jansson, J.O. (2008), "Public transport policy for central-city travel in the light of recent experiences of congestion charging", *Research in Transportation Economics*, 22: 179-187, https://doi.org/10.1016/j.retrec.2008.05.027.

King, D.A., M. Manville and D.C. Shoup (2007), "Political calculus of congestion pricing", *Transport Policy* 14(2), 103-180. https://ideas.repec.org/a/eee/trapol/v14y2007i2p111-123.html.

Lassiter, A. (2016), "Congestion pricing: A step toward safer streets?" MSc thesis, Columbia University.

Laval, J.A. et al. (2015), "Comparative analysis of dynamic pricing strategies for managed lanes", Southeastern Transportation Research, Innovation, Development and Education Center, Project 2012-089S, Final Report, https://trid.trb.org/view/1409555.

Li, M.Z.F. (2002), "The role of speed – flow relationship in congestion pricing implementation with an application to Singapore", *Transportation Research*, Part B, Vol. 36, pp. 731-754.

Littman, T.A. (2013), "Parking taxes: evaluating options and impacts", Victorian Transport Policy Institute. https://www.vtpi.org/parking_tax.pdf.

Lu, H. et al. (2017), "Analysis and Prediction on Vehicle Ownership Based on an Improved Stochastic Gompertz Diffusion Process", *Journal of Advanced Transportation*, Article ID 4013875, https://core.ac.uk/download/pdf/190719611.pdf .

May, A.D. et al. (2008), "Design tools for road pricing cordons", in Richardson, HW. and Bae, C-H., *Road congestion pricing in Europe: Implications for the United States*, Cheltingham, UK: Edward Elgar, pp. 138-155, https://doi.org/10.4337/9781848441453.00013.

Millard-Ball, A. (2019), "The autonomous vehicle parking problem", *Transport Policy*, Volume 75, pp. 99-108, ISSN 0967-070X. https://doi.org/10.1016/j.tranpol.2019.01.003.

Mobility Pricing Independent Commission (2018), "Metropolitan Vancouver Pricing Study", May 2018, https://tenyearvision.translink.ca/-/media/tenyearvision/funding/metro_vancouver_mobility_pricing_study.pdf.

Mohring, H. (1972), "Optimization and Scale Economies in Urban Bus Transportation", *American Economic Review*, 62: 591-604.

OECD (2019), "Assessing incentives to reduce traffic congestion in Israel", OECD Publishing, Paris, https://issuu.com/oecd.publishing/docs/optimised_israel_congestion_brochure_high_res__pri.

Oosterhuis, F.H. and P.T. Brink (2014), *Paying the Polluter: Environmentally Harmful Subsidies and their Reform*, Frank Oosterhuis and Peter ten Brink, Editors, Edward Elgar, 2014 (pages 133-5).

Parry, I.W.H. and K.A. Small, (2009), "Should Urban Transit Subsidies Be Reduced?", *American Economic Review,* 99(3), 2009, pp. 700-724, https://www.aeaweb.org/articles?id=10.1257/aer.99.3.700.

Phang, S.Y. and R.S. Toh (2004), "Road Congestion Pricing in Singapore: 1975 to 2003", *Transportation Journal*, Vol. 43, No. 2 (SPRING 2004), pp. 16-25, https://www.jstor.org/stable/i20713560.

Poole, R. (2020), "The Impact of HOV and HOT Lanes on Congestion in the United States", *International Transport Forum Discussion Papers*, No. 2020/08, OECD Publishing, Paris, https://doi.org/10.1787/0b353b17-en.

Proost, S. (2018), "Reforming Private and Public Urban Transport Pricing", *International Transport Forum Discussion Papers,* No. 2018/15, OECD Publishing, Paris, https://doi.org/10.1787/3567dda4-en.

Simoni, M.D., et al. (2019), "Congestion pricing in a world of self-driving vehicles: An analysis of different strategies in alternative future scenarios", *Transportation Research*, Part C: Emerging Technologies, Volume 98, 2019, Pages 167-185, ISSN 0968-090X, https://doi.org/10.1016/j.trc.2018.11.002.

Small, K.A., C. Winston and J. Yan (2006), "Differentiated road pricing, express lanes, and carpools: Exploiting heterogeneous preferences in policy design", Brookings-Wharton Papers on Urban Affairs, 53-96, https://www.jstor.org/stable/25067428.

Theseira, W. (2020), "Congestion control in Singapore", *International Transport Forum Discussion Papers*, No. 2020/10, OECD Publishing, Paris, https://doi.org/10.1787/7d266609-en.

Transport for London (2020), "Annual report and statement of accounts, 2019-20". http://content.tfl.gov.uk/tfl-annual-report-2019-20.pdf.

Transport for London (2008), "Non-statutory consultation on the future of the Western Extension of the Congestion Charging Zone Report to the Mayor", http://content.tfl.gov.uk/executive-summary-western-extension-consultation-report.pdf.

Transport for London (2005), "Central London congestion charging: Impacts monitoring, third annual report", http://content.tfl.gov.uk/central-london-congestion-charging-impacts-monitoring-third-annual-report.pdf.

Winston, C. and Q. Karpilow (2020), *Autonomous Vehicles: The Road to Economic Growth?*, Brookings Institution Press, Washington, D.C., https://www.jstor.org/stable/10.7864/j.ctvwh8fdt.

Yang, H., W. Xu and B.S. He (2010), "Road pricing for congestion control with unknown demand and cost functions", *Transportation Research*, Part C Emerging Technologies, 18(2):157-175, https://doi.org/10.1016/j.trc.2009.05.009.

Ye, H., H. Yang and Z. Tan (2015), "Learning marginal cost pricing via trial and error procedure with day to day flow dynamics", *Transportation Research Procedia,* 7 (2015), 362 – 380, https://cyberleninka.org/article/n/538169.

Yong, C. (2020). "New ERP system: Ong Ye Kung on why on-board unit has 3 pieces and why no distance-based charging for now", *The Straits Times,* https://www.straitstimes.com/singapore/retaining-current-erp-charging-model-a-policy-decision-distance-based-charging-has-to-be.

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Decongesting our Cities

This report reviews a wide range of congestion control measures. It analyses their effectiveness, financial and operational requirements, implementation time and public acceptability. It focuses on the role of technology in addressing congestion, including sensors, wireless systems, traffic light optimisation and trip planning data. The report takes an in-depth look at the use of HOT lanes to control congestion, the different ways in which they can be used and their effectiveness relative to other initiatives. The report is based on discussions held during the September 2020 ITF Roundtable on Congestion Control Experience and Recommendations.

All resources from the Roundtable on Congestion Control Experience and Recommendations are available at:
https://www.itf-oecd.org/congestion-control-experience-and-recommendations-roundtable

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