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Pricing It Right for Climate

Using Mobility Pricing to Drive Down Transport Emissions in Metro Vancouver and Montreal

December 2020

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SERIES

This is the second in a series of reports and case studies investigating challenges and opportunities for reducing carbon pollution from the transportation sector in Canadian cities.

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FOREWARD

Cities around the world have been using mobility — or road/transport — pricing to successfully tackle traffic congestion. But in 2020, as the world grapples with responding to the COVID-19 pandemic, the second and longer-term emergency —climate breakdown — also demands urgent action. This report evaluates whether mobility pricing can help reduce transportation emissions and traffic congestion while ushering in a better quality of life in two Canadian cities.

Road transportation is responsible for a significant proportion of Canada's carbon emissions: 36 and 31 per cent, respectively, in Vancouver and Montreal, the two metro areas studied in this report. These emissions come from high reliance on SUVs, light trucks, diesel buses and transport trucks and limited uptake of electric vehicles. The sector needs deep emissions reductions. All policy options must be on the table.

It's time to shift the conversation about how we view transportation. Drivers believe roads are freely provided, yet governments are on the hook for costly construction and maintenance costs. Lost in the "free roads" mantra is the fact that when governments don't charge for road usage, they fail to account for the negative impacts to society, including swelling carbon emissions, congestion, air and noise pollution, oil dependence and traffic accidents. As a result, people drive more than they would if those "externalities" were fairly priced and pass over sustainable alternatives like transit, active transportation and carpooling.

Mobility pricing works to reduce congestion, but it has not captured the public imagination as a climate solution. Our earlier report ***Shifting Gears*** highlighted its role as a powerful lever that metro regions and cities could use to reduce carbon emissions as well as the distances vehicles travel. Yet public opposition to pricing measures is higher than for other climate policies. Road pricing, in particular, is almost always unpopular before it's implemented. Dislike of taxes and distrust of government are easy triggers for polarized conversations.

Improvements to urban design, public transit and active travel are also important measures to reduce distances driven. Luckily, mobility pricing generates revenue to invest in public transit, active transportation and other sustainable transportation initiatives.

Vancouver and Montreal's metro regions are not on track to meet their climate goals for 2030 and beyond. Over the past decade, both regions have studied road pricing measures. This report sets the stage to introduce mobility pricing in Metro Vancouver as a climate solution in the next few years and to explore the potential for such measures (including zones where higher-emissions vehicles are either banned or must pay a higher fee) in Montreal's 2020-2030-2050 climate plan.

Efforts to build public support and policy-maker buy-in will be essential. We asked the authors to review mobility pricing design features and implementation processes that could build this critical support. The report investigates how the policy can be designed to be fair and refrain from punishing already disadvantaged groups.

We release this report in the context of COVID-19, which continues to have substantial, and uncertain, impacts on travel patterns and choices. Although it's unclear whether or not behavioural changes will be temporary or permanent, the possibility of increasing vehicle use makes introduction of policies like mobility pricing more, not less, important. The current economic downturn makes opposition to any pricing schemes almost certain but doesn't negate the need to act. Experience from successful implementation in cities like Stockholm and London shows public support grows once people start to recognize the benefits of cleaner air and less time spent in traffic.

The clock is ticking on the need to drastically reduce the world's carbon emissions by 2030 or face the most dangerous impacts of climate disruption as outlined by the Intergovernmental Panel on Climate Change in its 2018 report. Policies that move us quickly to deep, long-term carbon emission reductions to meet targets set out in the Paris Agreement are essential. Bold climate action requires bold climate policies like mobility pricing. This report shows that, with good design to address equity concerns, such policies can not only meet climate objectives but also make cities more equitable and livable.

Theresa Beer, Transportation Policy Specialist

PHOTO: Richard Eriksson, CC BY 2.0

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EXECUTIVE SUMMARY

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BACKGROUND AND GOALS

Stringent climate policy is needed to avert the most dangerous impacts of climate change. The purpose of this study is to summarize the evidence for effectiveness and best practices in road or mobility pricing policies, with particular consideration for Metro Vancouver and Montréal – two large urban regions in Canada with deep GHG emissions reductions goals. We consider multiple social and sustainability benefits, but prioritize deep, long-term GHG mitigation goals; i.e., Paris Agreement targets for 2030 and 2050.

The scope of our review is mostly focused on cordon areas, fuel taxes and per kilometre fees, as well as the potential for low-emissions vehicle (LEV) or zero-emissions vehicle (ZEV) zones (where higher emissions vehicles are banned or must pay a higher fee). We divide our summary into evidence for pricing effectiveness, cost-effectiveness, equity, political acceptability and implementation strategy. We conclude with a list of key considerations for developing road pricing policies.

The core of this analysis is a summary and synthesis of the available literature on road pricing. While multiple sources are considered, we prioritize insights according to comprehensiveness, rigour and applicability to the case regions of Metro Vancouver and Montreal.

From this available evidence, we identify the following insights on road pricing, categorized within several criteria of policy analysis (elaborated further in the next few pages):

1. **Effectiveness:** Clear evidence shows stringent road pricing can make an effective contribution to GHG mitigation in the short and long run as a complement to an existing GHG reduction policy mix.
2. **Cost-effectiveness:** Most studies suggest road pricing will lead to a net social benefit, the primary one being reduced traffic congestion.
3. **Equity:** Any pricing program will affect users differently, which can have important equity impacts. Careful program design can greatly improve equity (including affordability of transportation alternatives) and perceived fairness.
4. **Political acceptability:** Opposition among citizens and stakeholders is typically the most important barrier to pricing implementation. Careful design and implementation can improve acceptability.
5. **Implementation process:** Successful implementation of road pricing hinges on the process. Support can be built through an "interaction-oriented" political process that includes meaningful public and stakeholder consultation and information sharing over time.

EVIDENCE TO SUPPORT ROAD PRICING

We draw evidence from a variety of studies and reports, including ex-post analyses and modelling or simulation studies. Table E1 summarizes some of this evidence across the broad categories of: i) cordon or area pricing, ii) VKT/fuel/carbon pricing, and iii) ZEV zones or exemptions. Note that these three categories are not mutually exclusive; a road pricing approach could combine two or all three elements.

TABLE E1: Summary of evidence, across different design features (not mutually exclusive design)

	Cordon/area pricing	VKT/fuel/carbon pricing	ZEV zone/ exemptions
Effectiveness			
GHG mitigation	• Moderate potential	• Higher potential	• Unclear (especially with other ZEV policy)
Co-benefits	• Can target congestion • Can manage air pollution hot spots	• Some air pollution relief • Some congestion benefit	• Can manage air pollution hot spots
Cost-effectiveness	• Likely net benefit, with congestion relief	• Likely net benefit, complementing regulations	• Unclear
Equity	• Some inequity impacts (needs careful design)	• Some inequity impacts (needs careful design)	• Some inequity, likely income inequity in particular
Acceptance			
Public	• Significant opposition, with possible growing support if congestion improved	• Significant opposition (more support for VKT-based insurance)	• Probably higher opposition
Commercial/ freight	• Operators might support, with demonstrated congestion relief	• Less likely to support	• Less likely to support
Implementation potential and challenges	• Needs new infrastructure • Needs simple design, clear communication of impacts • Use a trial or not?	• Can work with existing systems (carbon price, fuel tax, insurance)	• Same as cordon area

Effectiveness: Clear evidence shows road pricing schemes can help a region reduce GHG emissions from road transportation, in the range of two to 10 per cent for cordon areas, and as high as eight to 13 per cent for prices per VKT as well as fuel taxes.[1-3] GHG reductions are likely to be greater for systems that are designed for climate targets rather than congestion management. Deeper reductions (15-40%) are theoretically possible in the long term (over several decades), with a much stronger tax[2,4] and/or if road pricing is combined with several complementary measures, including greatly improved transit service and active travel infrastructure.[5-7] Generally, GHG mitigation and travel reduction are more likely to be realized among passenger vehicles, where pricing can help avoid rebound effects from new mobility innovations that might reduce travel costs per person-kilometre travelled or VKT – namely ride-hailing and automated vehicles.[8,9] Freight (tonne-km travelled) and commercial travel might be less responsive to pricing, at least in terms of VKT and overall GHG impacts,[2,10,11] though more research is needed. There is much less research and experience with LEV/ZEV zones, but the evidence suggests that LEV/ZEV exemptions from road pricing might help such a policy reduce GHG emissions. However, it is plausible that a ZEV zone will not result in a net provincewide increase in ZEV sales when implemented in a region that already has a ZEV sales mandate in place (such as British Columbia and Quebec).

Cost-effectiveness: A number of studies consider economic efficiency or "cost-effectiveness" of road pricing. Typical measures include impacts on GDP, consumer welfare or industry profit. Generally, findings show a net social benefit from pricing, primarily from reductions in traffic congestion.[12] For example, one study finds that pricing can reduce congestion costs by 16 to 27 per cent in Greater Los Angeles.[13] Road or fuel pricing is also found to be an efficient complement to existing vehicle efficiency regulations, such as national vehicle emissions standards, largely due to the mitigation of potential rebound effects.[14] Economic impacts to heavy-duty vehicles are more uncertain. Some initial evidence suggests there is not a substantial economic impact (only a slight reduction in GDP and employment).[15]

Equity or fairness: The equity impacts of road pricing are much more controversial, and varied by study. Impacts can be regressive or progressive, depending on region, design and study method.[16] In particular, the design of road pricing (areas affected, use of revenue recycling) will strongly affect the distribution of impacts among "winners" and "losers" in a given system. For example, one study finds that using revenues for tax cuts will provide greater benefits for high-income people, while using revenue for transit improvement brings a greater benefit to low-income people and women.[17] Another study finds that pricing that does not vary in time will have a worse impact on low-skill, low-income workers.[18] As a particular challenge, one study points out that more efficient road pricing options might be less equitable, and vice versa[19] – though, again, careful design of revenue recycling and tax/toll exemptions can likely help to mitigate inequitable effects.

Political support: Lack of political acceptability is typically considered to be the largest barrier to road pricing implementation. For the most part, pricing measures face the most opposition among citizens relative to other climate policies,[20] and road pricing in particular almost always has low popularity prior to implementation.[21] A common theme is that stakeholders and citizens do not believe the measure will be effective or efficient,[22] at least partly due to the perception of having to pay for something that was "free" in the past,[23] or that the price impacts will be somehow unfair. Support and opposition vary among other stakeholders as well. Opposing political parties will typically debate road pricing, selecting competing frames that serve their own interests;[24] for example, campaigning against the measure and positioning themselves as defending the public against a "tax grab." While some research suggests that freight road users might have high opposition to road pricing,[25] stakeholder consultation in Metro Vancouver suggests commercial stakeholders may be supportive, in particular if there are substantial improvements in congestion and travel reliability.[26]

Implementation process: Several measures are recommended to improve the acceptability of road pricing, including:

- **Build trust and collaboration into the process,** including efforts to improve transparency in decision-making (including use of revenues) and allowing input from affected individuals;[16] use of an interaction-oriented policy process, with a trial period followed by a bilateral information sharing and in some cases a referendum;[27] and ideally building trust and cooperation among political parties.[28]
- **Careful design of pricing,** including use of revenue recycling for some mix of road, transit and safety improvement, as well as tax cuts;[16,29] packaging pricing within integrated policy plan;[23] keeping with a simple design, such as flat rate per kilometre, rather than numerous time and cordon rules.[30]
- **Effective communication** with stakeholders, including clear articulation of benefits,[31] as well as successful case studies and forecasts;[23] perhaps increasing citizen awareness and familiarity with the proposal;[32,33] assuring privacy and equity.[27]
- **Selecting frames that resonate with stakeholders,** such as focusing on pro-social outcomes (less pollution, improved transit, easier travel or access for all)[23,31] or the "polluter should pay" principle;[34] providing equity in a way that is valued for that region;[27] adjusting frames to connect with the region as experience is gained.[24]

KEY CONSIDERATIONS FOR ROAD PRICING DESIGN AND IMPLEMENTATION

From this available evidence, we identify four broad categories of considerations and discussion points to consider when developing a road pricing policy, including one that would apply to Metro Vancouver or Montreal. We limit our considerations to broader concepts, although many specific details must be determined for a particular program, including geographic scale, type of fees (dynamic versus flat rates) and technology type for administering fees. Specific details will have to be determined for each region case-by-case.

First is the overall type of road pricing. Climate benefits are maximized with a strong fuel tax or per VKT fee and should be pursued if politically possible. Area- or cordon-based approaches offer a more flexible approach that can also manage congestion and air pollution hot spots. An area- or cordon-based approach should be kept simple – for example, with flat fees during the daytime – as this tends to be more acceptable to the public and follows successful approaches in London and Stockholm. Finally, a full "ban" of higher-emitting vehicles in a given region seems likely to provoke particularly strong opposition, where benefits are unclear due to limited research. ZEV/LEV adoption might be better supported through exemptions from road pricing, though even the impact of this action is unclear in regions that already have a strong ZEV sales mandate.

Second is the use of revenues, which can greatly affect equity impacts, perceived fairness and overall acceptability of the pricing plan. Investment in transit and active travel will certainly complement the climate (and congestion) benefits of road pricing. However, acceptability can be boosted with some amount of road improvement and/or tax cuts as well (that is, cuts to income tax, corporate tax or goods and services taxes). Further, some amount of revenue could be used as rebates or credits for those unfairly impacted by the tax, such as low-income households or households in areas with relatively little transit service.

Third is the specification of exemptions. For equity impacts, regions should include exemptions for people with disabilities, as well as emergency vehicles. Some commercial vehicles could be considered for exemption. The case of freight is more complicated. Although freight exemptions are attractive (at least to boost political acceptability), freight is a major source of air pollution and GHG emissions. Further exemptions could be considered for various strategic purposes that line up with sustainability goals, such as "pooled" ride-hailing vehicle trips (where multiple strangers are matched into a single, streamlined trip; e.g., Uber Pool). As noted, pricing could be reduced or fully removed for passenger and freight ZEVs, or even for smaller/more energy efficient vehicles (LEVs), which could potentially support adoption of such vehicles in the long run. Again, that impact is unclear when a region already has a strong ZEV sales mandate.

Fourth is the implementation and consultation process. Program design and overall implementation should prioritize gaining support from as many stakeholders as possible (and ideally, among multiple political parties). Clear benefits should be offered for drivers (reduced congestion), transit users (better services), businesses (improved traffic flow, perhaps exemptions for their vehicles) and negatively affected sub-groups (e.g., compensation credits/ rebates). Other regions have had some success with a program that includes one or more demonstration/trial and referendum phase (in that order), to effectively try out the pricing policy before committing. However, a referendum might not fit with the political or governance culture of a given region, such as Metro Vancouver, which has more experience with consensus building among regional mayors and little history with direct democracy (i.e., referenda) on matters of transportation. In this case, a referendum also brings the risk of the region having to eventually abandon a program (if voted down) after substantial investment in the trial. Relatedly, the pricing scheme needs to be communicated and framed in a way that best resonates with the region, effectively building trust in the policy administrator and program more generally. The literature offers examples and general guidelines for communication, though a program really needs to be customized to the unique context of a given region.

RECOMMENDATIONS FOR METRO VANCOUVER AND MONTREAL

As a final component to this report, we consider how the insights from this broad evidence base may suggest specific recommendations for Metro Vancouver and Montreal in achieving 2030 and 2050 GHG mitigation goals.

Most centrally, we recommend that these regions implement road pricing among their leading mechanisms to reduce GHG emissions from road transportation. Our specific recommendations are based on the key considerations noted above and are listed in Table E2.

TABLE E2: Summary of recommendations

Design consideration	Recommendations	Considerations and alternative actions
Type of pricing	• Strong enough price to have significant traffic impact • Keep it simple • Pursue carbon/fuel/VKT tax for maximum GHG benefit • Also consider cordon pricing, using natural boundaries (waterways), with simple time structure (e.g., daytime)	• Carbon/fuel taxes can build off existing systems • Price per km (VKT) is more challenging to implement and explain • ZEV zone could be effective, but probably less acceptable
Use of revenues	• Make strategy transparent • Address stakeholder concerns • Probably a mix of allocation to program costs, public transit, active travel, roads, as well as stakeholder credits and/or tax cuts	• Customize based on regional consultation • Assure that strategy still supports GHG reductions
Exemptions	• Provide exemptions for people with disabilities and emergency vehicles • Carefully consider other exemptions; e.g., residents within cordon area or commercial vehicles • Consider exemptions for pooled vehicles and pooled ride-hailing	• Don't exempt too much, or the policy won't work • Charges should ideally apply to most or all commercial and freight vehicles • Unclear if ZEV/LEV exemptions will have an impact in regions with ZEV sales mandate
Implementation process	• Implement with intentional strategy, in stages with careful policy framing • Include clear consultation/ communication stages with two-way information sharing • Consider a trial of some sort • A post-trial referendum might work in some cases, but only if it fits with governance culture • Monitor and report costs and benefits (even after implementation)	• Avoid excessive delays • Avoid changes that dilute policy strength • Carefully select any trial period (if at all) • Referendum is risky but can add legitimacy

We again recommend that road pricing be viewed as part of the broader mix of transport and climate policies. Many of the policies and strategies noted in our 2019 *Shifting Gears* report[35] will be important complements to a road pricing strategy, including continuation of strong provincial/national-level regulations (vehicle emissions standards, low-carbon fuel standards and ZEV sales mandate) and carbon pricing. Further, metro regions and cities will want to support active travel, public transit and improved quality of the built environment (including density, diversity and transit-oriented development).

Finally, we note that road pricing design should take a long-term view, anticipating and complementing new forms of mobility. In particular, road pricing can be one of the most effective ways to responsibly guide the rollout of car-sharing, ride-hailing and vehicle automation technologies, to assure they lead to substantial GHG reductions and avoid rebound effects from cheaper travel modes.

1. INTRODUCTION

PHOTO: Nady, Adobe Stock

Globally, the transportation sector is responsible for almost one-quarter (23%) of total energy-related carbon dioxide equivalent emissions.[36] These proportions are even higher in some parts of Canada – 40 per cent for British Columbia, 45 per cent for Metro Vancouver[i] and 40 per cent for the urban agglomeration of Montreal.[ii] The majority of these emissions are from road transportation, including passenger vehicles (light-duty cars and trucks) as well as buses and heavy-duty trucks used for goods movement (or freight).

Our present focus is on the potential for road pricing to contribute to deep GHG mitigation goals in the road transport sector while providing other benefits such as complementing existing regulations, managing congestion and generating revenue for public transit and active travel infrastructure.

In our 2019 *Shifting Gears* report,[35] we reviewed the broad literature and case studies to summarize evidence for the most effective climate policies for the road transportation sector in British Columbia and Metro Vancouver. We saw particularly strong evidence that regions need to craft an integrated set of stringent climate policies for road transport, or a “policy mix,” to meet long-term goals.[37] *Shifting Gears* recommended that such a mix be led by strong regulations (a vehicle emissions standard, low-carbon fuel standard and/or ZEV sales mandate), in addition

i Climate 2050: Strategic Framework

ii Ville de Montréal. (2019). Inventaire 2015 des émissions de gaz à effet de serre de la collectivité montréalaise, une production du Bureau de la transition écologique et de la résilience. Repéré le jour/mois/année à ville.montreal.qc.ca/pls/portal/docs/page/enviro_fr/media/documents/VDM_InventaireCollectiviteGES_2015.PDF to a suite of complementary policies that can help to reduce vehicle travel (vehicle km travelled or VKT). While improvements to urban design, public transit and active travel are all important measures to support VKT reduction, **we identified road pricing as the most powerful lever that metro regions or cities could administer for GHG and VKT reduction.**

The purpose of this report is to summarize the evidence for best practices in road pricing. We focus on the implications for two regions: Metro Vancouver and the urban agglomeration of Montreal. Both regions have set deep climate mitigations goals and already have existing mixes of climate policies for road transportation in place at the national, provincial and metro and/or city levels. Further, both metro regions are not yet on track to meet their GHG goals for 2030 and beyond, and have been considering road pricing measures at various times over the past decade.

Road pricing is a broad category of pricing mechanism that can serve to reduce VKT, congestion and GHG emissions. One researcher provides a succinct summary of the need for road pricing: “Governments give drivers free land; people as a result drive more than they otherwise would.”[38] Put another way, road pricing can put a monetary value on the various “externalities” of vehicle usage; that is, the broad set of negative impacts to society such as GHG emissions, congestion, air pollution, oil dependence and traffic accidents. Economic theory indicates that setting a price that reflects these externalities will reduce vehicle usage to an “optimal” level, reducing GHG emissions, congestion and other negative impacts.

Our review considers several policies that could fit within the concept of road pricing:

- **A fuel tax or carbon tax,** which increases the price per unit of gasoline or diesel, so charges reflect the overall amount of driving (VKT) and efficiency of the vehicle used. It produces an incentive for reduced VKT, as well as for using more fuel-efficient vehicles.
- **VKT pricing** (or distance-based pricing) is charged based on the overall usage of the vehicle (creating a disincentive for all vehicle travel), such as a “pay as you go” insurance plan. Such systems can be designed to account for the carbon intensity of travel (e.g., with reduced rates for smaller vehicles or zero-emissions vehicles) but do not directly address congestion areas (or timing).
- **Cordon pricing** applies a charge to drive into a particular area, such as a downtown core.
- **Congestion-based pricing** charges higher prices to use roads at peak times of day. The primary goal is usually to reduce peak congestion, not necessarily to reduce overall VKT.

Further, there are many different ways to design a road pricing policy. Features include the type of pricing scheme, such as those listed above, as well as the magnitude of price and its variation across vehicle types, locations and time. Additionally, the design must include any necessary exemptions (e.g., specific groups of people or vehicle types) and a plan for use of the revenue, such as covering the system’s operating costs, funding public transit and road infrastructure projects and/or reducing other transportation-related taxes.

We also consider the potential role of low-emissions vehicle (LEV) or zero-emissions vehicle (ZEV) zones (which we will call "ZEV zones"), where higher-emissions vehicles are banned or must pay a higher fee. The literature is much richer for pricing, but we include ZEV zone insights where available. We do not explore the role of parking pricing, which includes fees that can discourage driving to particular areas, but we acknowledge that parking is an important consideration for any road pricing plan, and an important area for further research.[39]

This report's goal is to help advance prospects for implementation of mobility pricing in Metro Vancouver in the near term and to explore the potential for such measures (including ZEV Zones) in Montreal's 2020-2030-2050 climate plan.

Our focus is on the goal of achieving deep GHG emissions targets by 2030 and 2050 — where most regions of the world will need more stringent policy to do so. Road pricing is most commonly conceived as a way to fund road management, control congestion or reduce traffic in an urban area. However, road pricing can also reduce GHG emissions and support other VKT reduction strategies, such as increased use of transit and active travel. Further, as we point out in this review, the design of a road pricing scheme comes with trade-offs among some goals; for example, an optimal program for GHG mitigation might differ from a program that prioritizes congestion relief.

This report also takes a real-world view of the challenges to implementing road pricing measures – mainly stakeholder and public opposition. As reported in the *Metro Vancouver Mobility Pricing Study* in 2018, "Skepticism and low support for a decongestion charge were heard throughout the project with comments including 'it will not work,' 'this is another tax grab,' 'this is unaffordable,' and 'it is penalizing.'" Efforts to build public support and policy-maker buy-in are essential, which will likely include addressing any potential equity concerns. Some organizations will mobilize against congestion pricing. Public dislike of taxes and any distrust of government could be readily activated to increase opposition to congestion pricing. One hypothesis is that mobility pricing could be defeated with the implementation of a weak and ineffective road price that does not materially affect traffic. Thus, critics would be able to point to unchanged traffic volumes as a sign of failure. Finally, if the province does not support pricing or allow municipalities to make their own decisions, mobility pricing is less likely to be implemented. Our review will consider the conditions that were present in several case studies of "successful" road pricing implementation.

With this complexity in mind, our report considers evidence in the following categories of policy analysis:

1. **Effectiveness**: What are the impacts of road pricing on several key policy goals, namely reducing GHG emissions and vehicle travel (VKT)? How do impacts vary by passenger versus freight or commercial travel? For certain schemes that provide exemptions or discounts for ZEVs or energy-e ficient vehicles, what is the impact on fleet composition in the long term?
2. **Cost-effectiveness:** How does road pricing affect GDP, consumer welfare, industry profit or other "economic" measures that are typically considered?

3. **Equity impacts:** Who are the "winners" and "losers" of such a policy, and is this "fair"? How can fairness be affected by context and policy design?
4. **Political support:** What are the rates of citizen and stakeholder support and opposition for road pricing programs?
5. **Implementation:** What is the ideal implementation process for road pricing in a given jurisdiction?

We also note that while our focus is on one category of policy mechanism, our review considers interactions across policies in a given policy mix. Most developed countries already have a number of related transport and energy policies in place, especially vehicle emissions or efficiency standards (e.g., CAFE in the U.S. and EU 2030), low-carbon fuel standards, ZEV sales mandates and other financial incentives (e.g., for transit) and disincentives (e.g., other pricing mechanisms). In real-world policy-making, road pricing presents a promising option to complement existing policies rather than being a substitute.[37]

We also release this report in the context of COVID-19, which to date has had substantial impacts on travel patterns and mode preferences. In many regions, including Metro Vancouver, transit ridership has substantially decreased as part of efforts to socially distance, including increased home-based working and schooling, decreased travel in general and increased preference for the private space offered by personal vehicles. This disruption has also revealed some of the challenges of the current funding model for transit systems, when revenues from fuel purchases and transit ridership have substantially declined. While the future of COVID-19 (and its long-term impacts on traveller behaviour) is highly uncertain, we believe there are many important reasons to actively pursue road pricing programs – notably for the GHG mitigation requirements and other sustainability goals already noted and summarized further in this report.

The next sections provide further background details of our two case studies: Metro Vancouver and Montreal. We then summarize our approach (Section 4), before summarizing the evidence in Sections 5 through 9. Sections 10 through 12 highlight research gaps, key considerations and recommendations from this evidence base.

2. BACKGROUND: METRO VANCOUVER, BRITISH COLUMBIA

PHOTO: Samuel Sianipar, Unsplash

TRANSPORT AND GHG TARGETS

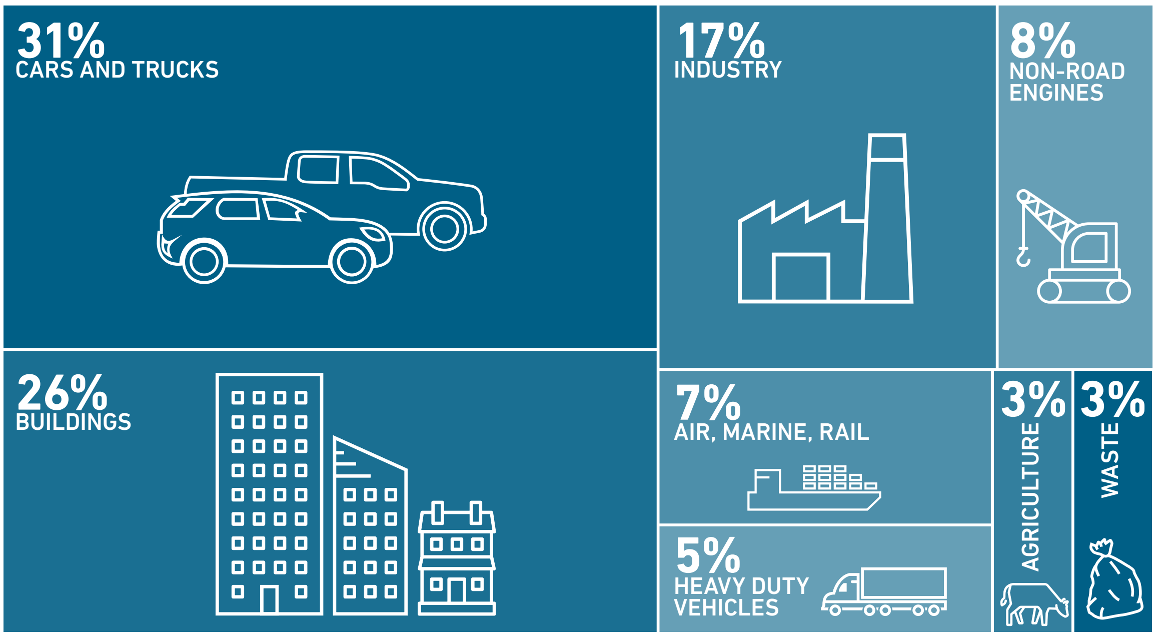
To start, the transportation sector is a major source of GHG emissions in British Columbia, and stringent policy is needed to reverse the trend of emissions growth. While current policy plans are fairly ambitious, there is still a gap between anticipated and targeted GHG mitigation goals.

In May 2018, the Province of British Columbia set goals to reduce GHG emissions relative to 2007 levels, with reductions of 40 per cent by 2030, 60 per cent by 2040 and 80 per cent by 2050. In 2016, B.C.'s transportation sector accounted for about 39 per cent of total GHG emissions. Further, these emissions have been growing. Between 2007 and 2016, provincial passenger vehicle emissions increased by 15 per cent, and heavy-duty truck emissions increased by eight per cent.[40]

The provincial government is taking climate change seriously, and in 2018 its ***Clean BC*** report outlined the policy mix it plans to implement to meet 2030 goals. The mix includes regulations (a strong ZEV mandate, a low-carbon fuel standard and vehicle emissions standards), ZEV purchase incentives, deployment of ZEV charging infrastructure and improvements to public transit and active transport infrastructure. However, these initiatives together fall short of the 2030 goals – in the government's own analysis adding up to about 19 Mt of GHG mitigation, rather than the required 25 Mt. A second phase of ***Clean BC*** is intended to tackle this mitigation gap.

Metro Vancouver is a federation of almost two dozen local governments that collaborate to deliver regional-scale services to a population of 2.5 million people in the southwestern area of mainland British Columbia. Notably, Metro Vancouver monitors and manages regional air quality and is therefore involved in transportation and GHG emissions planning. The transport sector accounts for about 43 to 45 per cent of GHG emissions in Metro Vancouver. Figure 1 depicts how emissions are distributed among on-road cars and trucks (31 per cent), heavy-duty vehicles (five per cent), and air, marine and rail (seven per cent).[iii]

Figure 1: Summary of GHG emissions sources in Metro Vancouver, adding up to 14.7 Mt GHG



Source: Climate 2050: Strategic Framework

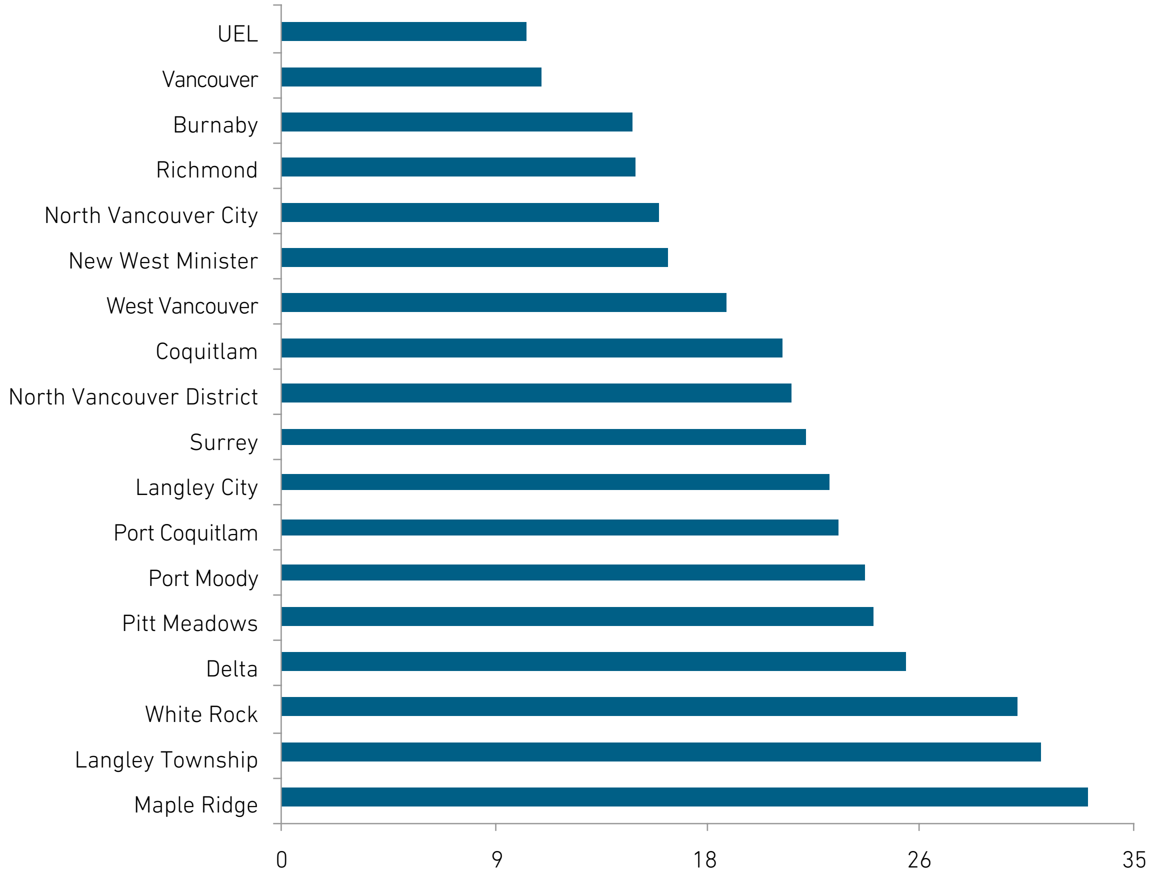
Metro Vancouver's future trends in road transport GHG emissions will be largely impacted by population growth and travel demand. In 2011, residents on average drove personal vehicles about 18 VKT per weekday, per capita (Figure 2 splits this up by municipality). Notably, the population of Metro Vancouver has been growing by about 30,000 residents per year, and is expected to reach 3.6 million by 2050. If driving patterns continue per capita, VKT in 2050 would be 45 per cent higher than 2016 levels, and 70 per cent higher than 2007 levels. Such growth in VKT could cancel out the GHG benefits provided by strong regulations and other climate policies.

Before social-distancing measures for COVID-19 began in March 2020, about 72 per cent of personal trips in the region were made by vehicles, compared to 16 per cent by walking and cycling and 12 per cent by transit (based on 2017 trip diary).[iv] Social-distancing measures have led to a decrease in transit usage, and it is unclear if public transit ridership will return to these levels as social-distancing constraints are removed.

iii We do not presently focus on GHG emissions from air, marine or rail, which make up about 15% of Metro Vancouver's transportation GHG emissions.

iv Metro Vancouver, Metro 2040 Dashboard: Mode Share, accessed October 15th 2020 at link

Figure 2: Vehicle km travelled (VKT) per capita, by municipality in Metro Vancouver, 2017



Source: 2017 Metro Vancouver Regional Trip Diary Survey, TransLink, https://public.tableau.com/profile/translink#!/vizhome/Trip_Diary_2017/TripDiary2017?utm_source=sootoday.com&utm_campaign=sootoday.com&utm_medium=referral

Similar to the province, Metro Vancouver aims to achieve carbon neutrality by 2050, with an interim target of 45 per cent reduction in emissions by 2030 relative to 2010 levels. According to the 2020 Transportation Discussion paper,[v] Metro Vancouver intends to eliminate GHG emissions from transportation by 2050 with the goals of: i) "all travel within the region is made by active transportation or using zero-emission technologies powered by clean, renewable energy," and ii) "all heavy-duty trucks, marine vessels and rail locomotives operating within the region use zero emission technologies powered by clean, renewable energy." Notably, of the two "big ideas" identified in the 2020 Transportation Discussion paper, the first is to "reduce emissions through mobility pricing," including the potential for an "ultra-low emission zone."

Prior to the onset of COVID-19 social-distancing protocols, Metro Vancouver's transit agency, TransLink, was planning to invest in several public transit initiatives to help increase transit ridership over the next decade (2018-2027 Investment Plan, released June 2018). TransLink's proposed Phase 2 aims to increase transit journeys to 316 million by 2027 (from 250 million

v http://www.metrovancouver.org/services/air-quality/AirQualityPublications/CleanAirEmissionSummary-Transportation.pdf in 2018), through a number of projects that include new rapid transit, upgrades to existing passenger rail and increased overall bus service. Phase 2 proposes some form of road pricing to "reduce congestion and overcrowding, improve fairness and support transportation investment" – though GHG emissions mitigation is not mentioned as a goal of such a pricing mechanism. Given the impacts of COVID on transit usage, it is not clear if these plans will still hold.

ROAD PRICING EXPERIENCE

Road pricing has been a contentious issue in Metro Vancouver over the past decade. Metro Vancouver's recent experience with it is limited to the tolls on two bridges that span the Fraser River at the eastern side of the Metro area: the Port Mann Bridge and the Golden Ears Bridge. Tolls began on the Port Mann Bridge in 2012 after it was rebuilt and expanded, costing $3 per crossing for a light-duty vehicle and between $6 and $9.50 for larger commercial vehicles.[vi] Tolls on the Golden Ears Bridge started when the bridge was completed in 2009 and were charged at a similar rate.[vii]

In 2017, the newly elected provincial government followed through with its plan to remove the tolls on the basis of equity.[viii] The rationale was that it was unfair to have a subset of citizens paying tolls on two specific routes (while other citizens who travelled different routes did not have to pay). There was some pushback against this decision due to the lost revenue and addition to the provincial debt,[ix] and some regional mayors were concerned that traffic congestion on those routes would increase. Traffic monitoring revealed that travel on those routes increased by 30 to 40 per cent once the tolls were removed, though travel on surrounding routes also declined.[26] Overall crossings over the Fraser River increased by seven to nine per cent, resulting in increased travel times between most regional centres. Following removal of the tolls, the idea of broader road pricing in Metro Vancouver was noted as a future alternative being examined by regional mayors for managing congestion and funding transportation infrastructure.[x]

Also relevant is Metro Vancouver's experience with a regional referendum on taxation for transportation funding. In 2015, a regional referendum (officially a plebiscite) rejected raising the provincial sales tax by 0.5 percentage points to fund transit (with 62 per cent against and 38 per cent in favour).[xi] This was the first referendum ever held in Vancouver on a transport issue, and seemed to work against the consensus-based model that Metro Vancouver normally

vi TrEO, 2015, Port Mann toll rates have changed, Accessed August 27, 2020, link

vii Translink, 2012, toll rates, accessed August 24, 2020, link

viii Tolls to be eliminated on Port Mann and Golden Ears bridges, CBC, Bethany Lindsay, August 25, 2017, accessed August 27, 2020. link

ix Cost of debt on Metro Vancouver bridges to be shared by all B.C. taxpayers, Vancouver Sun, August 26, 2017, Jennifer Saltman, Accessed August 27, 2020, link

x Cost of debt on Metro Vancouver bridges to be shared by all B.C. taxpayers, Vancouver Sun, August 26, 2017, Jennifer Saltman, Accessed August 27, 2020, link

xi City of Vancouver, Metro Vancouver Transportation and Transit Referendum, accessed September 2, 2020, link follows among the 23 municipalities represented on the Mayor's Council.[41] The lack of history and short lead time suggests the referendum might have been a strategic effort by the provincial government at the time to avoid responsibility for the outcome. As noted by Legacy and Stone (p. 298)[41]:

> "In what appears to have been a tactical move to evade responsibility for deciding a new revenue stream for transit, the province imposed a plebiscite on new revenue sources for transit, while at the same time committing funding to large-scale road-based projects in other parts of the region without requiring a plebiscite."

According to citizen polling, some local mayors and those who were campaigning against the tax increase, rejection of the tax seems to have been more of a vote of non-confidence in the transparency and decision-making of the regional transit authority rather than an outright rejection of transit improvements.[xii] Interestingly, while the referendum was unsuccessful, it did motivate the formation of a strong coalition of "yes" stakeholders (in favour of pricing, public transit and environmental goals) that has persisted in supporting public transit initiatives.[41] On the "no" side, opposition was led by a taxpayer group that focused on mismanagement by TransLink, whose leadership has since changed. Empowered taxpayers used their role to critique governance.[42]

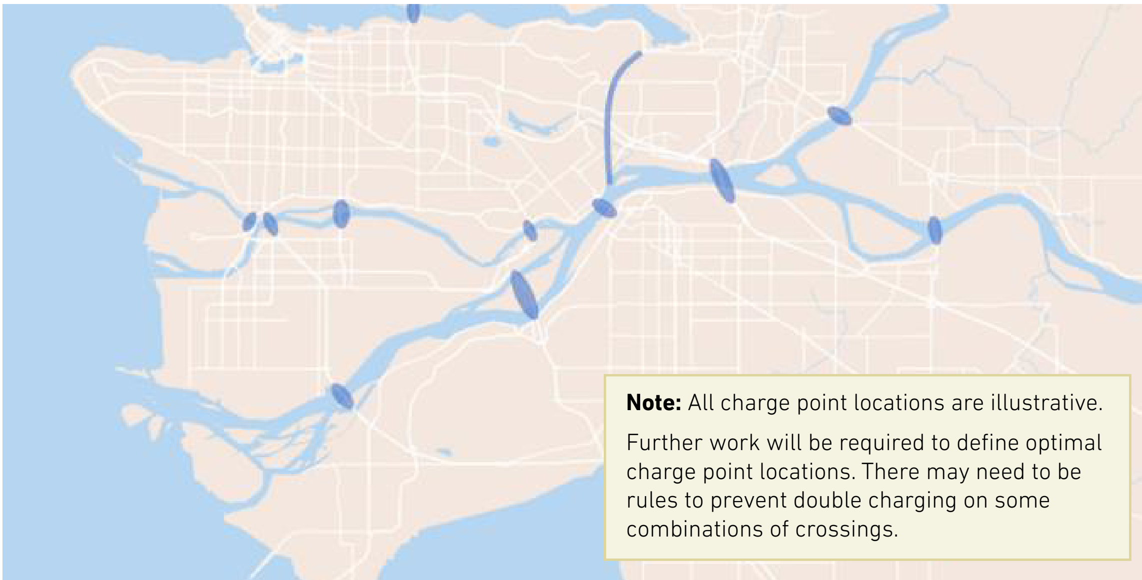
In 2017, the Mayor's Council and TransLink established the Mobility Pricing Independent Commission to study the potential for a pricing system that would manage congestion, promote fairness and support investment. In 2018, the commission released the *Metro Vancouver Mobility Pricing Study* in which it developed and analyzed several broad concepts for road pricing in Metro Vancouver, beginning what is expected to be a long and contentious policy discussion. The report focused on congestion, equity and investment – with relatively less emphasis on GHG emissions. The report was informed by extensive consideration of public and stakeholder concerns, where the authors describe pricing as a policy that is 'not for the faint of heart" and unpalatable for the public — an overall challenge to implement.[xiii]

As an illustration, the *Metro Vancouver Mobility Pricing Study* discussed a potential cordon pricing scheme, as well as a distance-based charge. The cordon scheme is illustrated in Figure 3, which the authors estimate would cost users $5 to $8 per day, and reduce congestion time by 20 to 25 per cent. Compared to a 2030 baseline, VKT would be reduced by four to six per cent and GHG emissions would be reduced by two to three per cent. The report also suggests the potential use of a pricing trial or pilot, potentially on a limited geographic area. To date, such a pricing scheme is still under consideration.

xii Globe and Mail, Vancouver-region voters reject sales-tax hike to fund transit projects, FRANCES BULA, JULY 2, 2015, Accessed August 19, 2020 link
Lesch (2018): https://munkschool.utoronto.ca/imfg/uploads/482/06_26_2018_matt_lesch_mind_the_funding_gap_0626___copy.pdf

xiii Mobility pricing commission recommends more study of road pricing for Metro Vancouver, CBC, Justin McElroy, May 24 2018, accessed August 27, 2020, link

Figure 3: Illustration of congestion point charge points for Metro Vancouver



Source: Mobility Pricing Independent Commission, 2018

Many of those involved in the study and development of a road pricing plan for Metro Vancouver recognize that it will need to be further refined and optimized over the next five to 10 years before it will have any chance of being implemented.[xiv]

In 2019, regional mayors chose to increase transportation funding by increasing the fuel tax that applies to Metro Vancouver by 1.5 c/L (~9%), combined with increased transit fares and sales tax on parking.[xv] In doing so, they secured funding from the provincial and federal governments on a three-way split of $7.5 billion investment in transit improvements.[xvi] The tax increase was seen as a measure of last resort given the unacceptability of raising property taxes and the 2015 rejection of a sales tax increase.[xvii] Unless road pricing (or some other revenue-generating strategy) is implemented in Metro Vancouver, transportation funding in the region will remain tied to more traditional sources, notably the provincial fuel tax, transit fares and property taxes supplemented with contributions from provincial and national levels of government. Fuel tax revenues are fairly uncertain over time and are likely to decline with increasing uptake of ZEVs. A more stable source of funding is needed to meaningfully invest in transit and active travel infrastructure.

xiv Mobility pricing: What happened? What's next?, Marc Lee, 2018, Canadian Centre for Policy Alternatives, link

xv Higher gas, parking taxes and transit fares in e fect for Metro Vancouver, CTV News, Maria Weisgarber, July 1, 2019. Accessed August 19, 2020 link

xvi CBC, Metro Vancouver mayors approve gas-tax increase of 1.5 cents a litre to fund transit plan, Justin McElroy, Jun 28, 2018. Accessed August 19 2020, link

xvii Ibid.

3. BACKGROUND: MONTREAL

PHOTO: Matthew Fournier, Unsplash

TRANSPORT AND GHG TARGETS

At the provincial level, Quebec has legislated GHG reduction targets of 20 per cent by 2020 and 37.5 per cent by 2030, relative to 1990 emissions levels,[xviii] which includes proportional reductions for the transport sector.[xix] The province also has an objective of an 80 to 95 per cent reduction from 1990 by 2050, outlined in the Subnational Global Climate Leadership Memorandum of Understanding. In 2018, Quebec's transportation sector accounted for about 43 per cent of total provincial GHG emissions. Further, these emissions grew by eight per cent over the previous decade.[xx]

The provincial climate policy mix is led by two main policy initiatives (with new policies expected to be tabled in later 2020):

- The carbon market, an emissions cap-and-trade system that applies a declining emissions cap to industry, electricity generation and fossil fuel distributors. The system is linked to the California emissions credit market through the Western Climate Initiative. All funds from the credit market are used to fund climate change adaptation and emissions reductions efforts (including PEV subsidies and transit funding).[xxi]
- The ZEV sales mandate, which requires a rising minimum quantity of light-duty ZEVs to be sold in Quebec. The sales requirement is 9.5 per cent in 2020, rising to 22 per cent in 2025. However, because it is a credit-based system, where longer-range battery-electric vehicles (BEVs) produced upwards of three credits, the actual required market share for ZEVs will likely be lower than the requirement.[xxii]

xviii Government of Québec, Québec's Commitments: Our GHG Emissions Reduction Targets, accessed August 19, 2020 at link

xix https://www.transports.gouv.qc.ca/en/Pages/sustainable-mobility-policy.aspx

xx Environment and Climate Change Canada, 2020, Canada's O ficial Greenhouse Gas Inventory, link, Accessed September 3rd 2020

xxi Government of Québec, The Carbon Market, a Green Economy Growth Tool!, accessed August 19 2020 at link

xxii Government of Québec, The zero-emission vehicle (ZEV) standard, accessed August 19, 2020 at link

The Montreal Urban Agglomeration (which we simply call Montreal in this report) is a region that consists of municipalities on the island of Montreal (as well as several adjacent islands), consisting of almost two million residents. The urban agglomeration sits within the Communauté métropolitaine de Montréal, a larger and more populous region (four million residents), which organizes and funds public transport, transportation infrastructure and other regional initiatives.[xxiii]

Montreal has a GHG emission reduction target of 30 per cent from 1990 by 2020 and a commitment for an 80 per cent reduction by 2050.[xxiv] The transportation sector is a significant source of urban GHG emissions in Montreal, accounting for 40 per cent of the total in 2015. The majority of emissions come from on-road light and medium/heavy-duty vehicles (31 per cent of urban emissions), with the remaining emissions produced by air, marine and rail travel and off-road vehicles (nine per cent of urban emissions).[xxv] Further, congestion costs in the region were found to have doubled over 10 years, to about $4.2 billion in 2018.[xxvi]

Montreal's plan to reach the 2020 target (and beyond) focuses mostly on subsidies and infrastructure to reduce vehicle travel (VKT) via mode switching and improved urban density, as well as vehicle electrification.[xxvii] The plan notes that funding sources should be diversified away from taxes that depend on fossil fuel consumption (e.g., the provincial fuel tax). Measures include the following:

- Sourcing additional funding from new development charges for buildings near transit stations and higher registration fees for higher-fuel-consumption vehicles.
- Acquiring hybrid buses and PEV fleet vehicles.
- Investing in transit and train infrastructure, and active transport networks.
- Investing in PEV charging infrastructure.
- Reducing the number of paid parking spaces and increasing the number of park-and-ride facilities.
- Focusing development and densification around existing and upcoming transit hubs.
- Supporting the use of zero- and low-emissions vehicles in car-share fleets by issuing them a greater proportion of the required parking permits.
- Supporting use of cargo bikes for urban deliveries.
- Launching a pilot program to better integrate carpooling and car-sharing with public transport.

xxiii Communauté metropolitaine de Montréal, À Propos, accessed October 15, 2020 at link

xxiv City of Montréal, Rapport Durable Montréal: Greenhouse Gases, accessed August 19, 2020 at link

xxv Ville de Montréal (2019). Inventaire 2015 des émissions de gaz à e fet de serre de la collectivité montréalaise, une production du Bureau de la transition écologique et de la résilience. Accessed September 3, 2020, link

xxvi https://cmm.qc.ca/wp-content/uploads/2019/04/20190401_TC_Financement_Rapport.pdf

xxvii Ville de Montréal (2018). Progress Report on Montréal's 2013-2020 Citywide Greenhouse Gas Emissions Reduction Plan, a publication of the Service de l'environnement, 64 pages

This plan fits within the broader CMM plan to define an urban perimeter to support dense and diverse development around public transit hubs, while raising the transit mode share to at 35 per cent during the morning rush hour by 2035.[xxviii]

A 2018 progress report on Montreal's GHG emissions reduction efforts indicated that these measures were not sufficient to meaningfully reduce VKT, car ownership and transportation emissions in the short-term.[xxix] Transit ridership remained more or less constant between 2013 and 2016 and car ownership was 31 per cent higher in 2017 relative to 1990. As one positive sign, between 2008 and 2017, the active transport mode share increased by 0.4 percentage points to 17.5 per cent of trips, mainly as a result of growth in cycling (57 per cent increase in mode share since 2008, reaching between two and four per cent of trips, depending on the season).[xxx]

ROAD PRICING EXPERIENCE

As of 2020, Montreal's experience with road pricing is limited to bridge tolls on a few routes. The A25 bridge onto the north side of Montreal Island has a time and day varying toll between $1.36 and $1.70 for light-duty vehicles. The A30 bridge also has tolls charging $3.30 per crossing. The new Champlain Bridge from the southeast was expected to have a toll. However, with the bridge now open, the federal government announced that it will not charge bridge users.

Nonetheless, road pricing has long been part of the policy discussion in the Montreal area. This could be in part due to the fact that Montreal has unique geography that lends itself to cordon pricing (Figure 4). The centre of the urban area is on an island, giving it a natural boundary, where there is significant commuting on and off the island. Some earlier City of Montreal transportation plans (2007 and 2008) supported the idea of road pricing as a way of funding road maintenance, but nothing was implemented. In 2019, a survey indicated that 40 per cent of people are somewhat or strongly in favour of zoned pricing as a means to fund public transit – specifically a cordon around the island of Montréal.[xxxi] Forecasts in the accompanying analysis indicated that this system could generate roughly $750 million per year. In response to this analysis in 2019, the mayor said Montreal is still not at the point of following the lead of other cities that have implemented road pricing.[xxxii] That said, pricing is being studied in the region, with one modelling study showing that a $0.15/km charge, which roughly increases variable transport costs by 25 per cent, could reduce transport GHG emissions by 25 per cent while likely providing traffic congestion relief in the Montreal area and creating a new source of revenue.[xxxiii]

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xxviii Communauté metropolitaine de Montréal, 2012, Plan métropolitain d'aménagement et de développement, accessed October 15th 2020 at link

xxix City of Montréal, Rapport Durable Montréal: Greenhouse Gases, accessed August 19 2020 at link

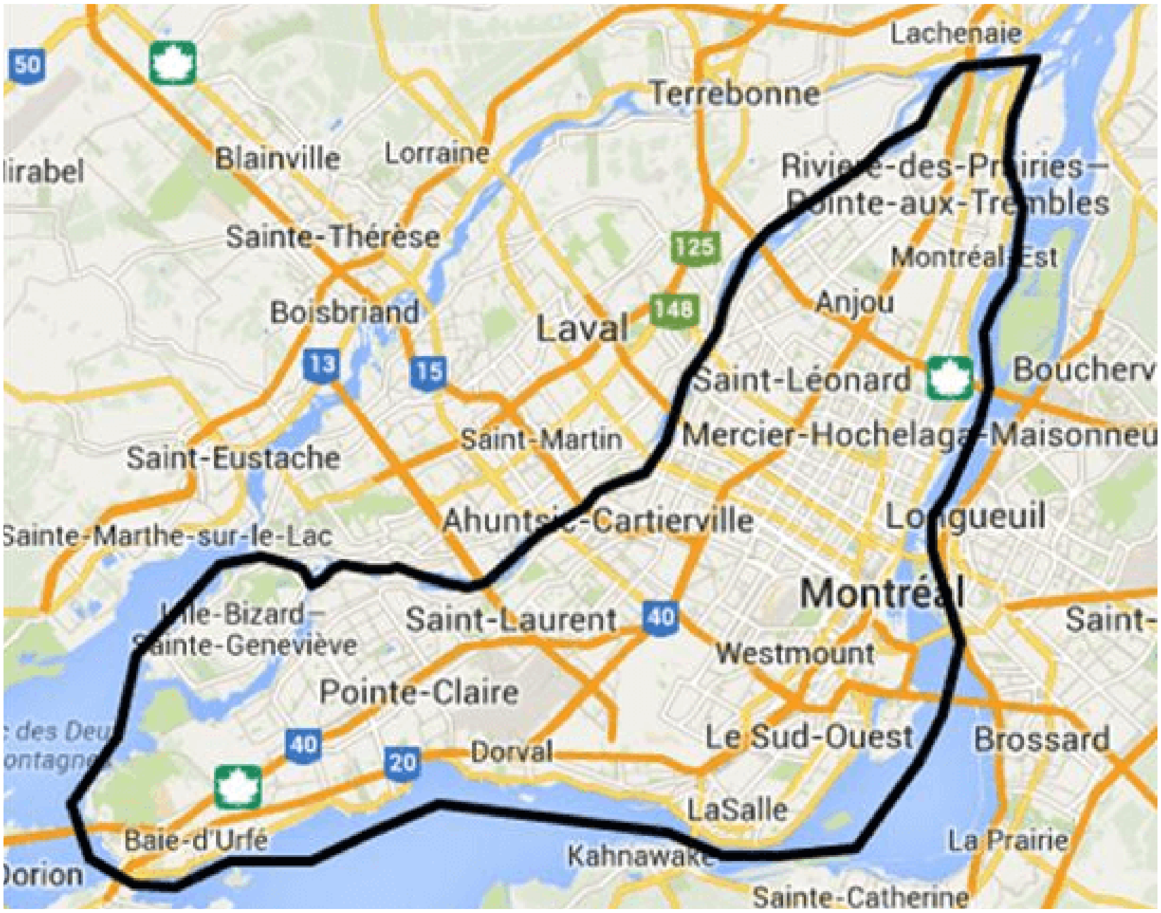
xxx Ville de Montréal (2018). Progress Report on Montréal's 2013-2020 Citywide Greenhouse Gas Emissions Reduction Plan, a publication of the Service de l'environnement, 64 pages. accessed August 19 2020 at Link

xxxi Communauté Metropolitane de Montréal, 2019, Sources de financement du transport collectif dans le Grand Montréal, Rapport final de la commission du transport de la communauté métropolitaine de Montréal

xxxii Montréal Gazette, April 9 2019, Allison Hanes, Should we put a price on congestion in Montreal? Link

xxxiii TRANSIT, l'Alliance pour le financement du transport collectif, 2018, Prochaine station, l'écofiscalité : Réduire les émissions de gaz à e fet de serre en transport au Québec en tarifant adéquatement les déplacements motorisés link

Figure 4: Illustration of potential cordon charge points for Montreal



Source: www.montreal-kits.com/montreal-maps.html

Likewise, there is no official plan to implement ZEV-only zones or other forms of road price/constraints that would support the adoption of ZEVs. As part of its 2018 election campaign, the Québec solidaire party committed to an outright ban on fossil fuel–powered light-duty vehicle sales between 2030 and 2040 – to increase the stringency of the province's existing ZEV mandate.[xxxiv] The party platform also suggested using a temporary bonus-malus system (feebate) to encourage the sale of electric vehicles, and banning fossil fuel–powered vehicles from an increasing number of roads. The party holds few seats in Quebec's National Assembly, and as of October 2020, these ideas have not yet had any effect on government commitments or legislation.

xxxiv Québec Solidaire (2018). Plan de transition économique - Québec solidaire présente son plan d'investissement en transport collectif. Accessed August 19 2020 at link

4. OUR APPROACH

PHOTO: Scott Graham, Unsplash

Our analysis is based on a summary and synthesis of available literature. We use our experience and expertise in this field to identify helpful and robust studies, evaluate their findings and extract evidence and insights relevant to Metro Vancouver and Montreal's plans for GHG mitigation.

While multiple sources are considered, we prioritize insights according to comprehensiveness and rigour. Studies can vary considerably in quality and relevance, and we generally find that peer-reviewed studies provide more careful insight than the grey literature (though there are exceptions), and that systematic literature reviews provide a broader evidence base than a single case study.[43] As such, we focus our evaluation on empirical and systematic reviews in the peer-reviewed literature, where available.

As noted in the introduction, we categorize evidence into the following categories of policy analysis:

1. **Effectiveness:** What are the impacts of road pricing on several key policy goals, namely reducing GHG emissions and vehicle travel (VKT)? How do impacts vary by passenger versus freight or commercial travel? For certain schemes that provide exemptions or discounts for ZEVs or energy-efficient vehicles, what is the impact on fleet composition in the long term?
2. **Cost-effectiveness:** How does road pricing affect GDP, consumer welfare, industry profit or other "economic" measures that are typically considered?
3. **Equity impacts:** Who are the "winners" and "losers" of such a policy, and is this "fair"? How can fairness be affected by context and policy design?
4. **Political support:** What are the rates of citizen and stakeholder support and opposition for road pricing programs?
5. **Implementation:** What is the ideal implementation process for road pricing in a given jurisdiction?

As part of this review, we consider evidence from several real-world cases from other countries, notably the five summarized in Table 1, which include:

- Singapore, which implemented area pricing in 1975, and later progressed to an electronic pricing system in 1998. (A new version is planned for 2023.)
- London (U.K.), which implemented a cordon area in 2003.
- Milan (Italy), which implemented a cordon area in 2008.
- Stockholm (Sweden), which implemented a cordon area as a trial in 2006, and then permanently in 2007.
- Gothenburg (Sweden), which implemented a cordon area in 2013.

These cases have some similarities, using cordon pricing to access a given area, with charges applied only during the daytime on weekdays. Importantly, these programs vary by stated goals (congestion, air pollution, funding infrastructure), as well as various design features including price level, differentiation across vehicle types, exemptions and revenue use. Despite these differences, estimates suggest that these programs have led to substantial reductions in traffic, as well as increases in public transit mode share. The details of these pricing schemes are summarized in Table 1. We will further summarize the estimated impacts and implementation details of these case studies in this review.

While case studies are helpful, there is little empirical evidence that directly addresses our focus on long-term GHG mitigation. That type of insight would require research on a stringent price that has been in place for multiple decades. For this reason, our review also considers forward-looking studies to help to fill this gap, namely quantitative modelling exercises. Ideally, such models account for important features of the transportation system, including realistic consumer and traveller behaviour, interactions across relevant transport, climate and energy policies, and long-term dynamics. Simulation of long-term impacts should ideally include several levels of choices, namely mode choice, vehicle ownership (number and type), residence and workplace location, and even activity planning. Pricing could also lead to reductions in travel demand, including increased uptake of telecommuting[44] and online shopping[45] – all of which seem more feasible since the observation of up to 50 per cent reductions in travel demand due to COVID-19 lockdown protocols.[46] As we will note, few modelling studies have followed such an ideal, comprehensive and long-term perspective.

TABLE 1: Summary of road pricing cases studies, adapted from [21,27,47-51]

Impact	Singapore	London (U.K.)	Milan (Italy)	Stockholm (Sweden)	Gothenburg (Sweden)
Details[a,b,c]					
Years in place	1975: Area pricing 1998: electronic	2003	2008	2006: Trial 2007: Permanent	2013
Goal(s) (in order)	Congestion	Congestion (travel time, goods movement), improved bus service	Air pollution, congestion	Congestion, environment	Infrastructure funds, congestion, air pollution
Type (control points)	Cordon and freeway pricing (66 points)	Cordon (area, 174 points)	Cordon (43 points)	Cordon (18 points)	Cordon (37 points)
Cost	0.3-1.7 Euro for conventional vehicles	Daily fee, GBP 11.50	2 to 10 Euro	Per crossing (either way), 10-20 SEK	Per crossing (either way), 8 to 18 SEK
Differentiation	Vehicle class		Vehicle emissions	"Clean car"	
Timing	7:30am-7:30pm weekdays	7am-6pm weekdays	7:30am-7:30pm weekdays	6:30am-6:30pm weekdays	6am to 6:30pm, weekdays
Exemptions	Emergency vehicles only	Buses, taxis, emergency vehicles, discount for residents (23% of total traffic)	Emergency vehicles, public transit, discount for residents	30% of total traffic	
Revenue use		Improved bus/rail systems		Transport infrastructure (local control of revenue)	Transport infrastructure
Impacts [a,c]					
Traffic volume	-40% to -45%	-18% to -21%[a]	-14% to -34% -49% HDV	-15% to -20%	-9% to -12%
Mode share	+21% transit	+59% bikes +7% to +18% transit	+6 to +9% transit	+5% to +9% transit	+6% transit
GHG emissions		-16%	-22%	-13%	-2.5%
Air pollution		-13 to -16%	-6% to -40%	-8% to -13%	
Implementation[b]					
Trial	No	No	No	Yes	
Referendum	No	No	Yes	Yes	Yes
Factors considered[b]					
Privacy	Yes	Yes			n/a
Equity	Yes	Yes	Yes	Yes	n/a
Complexity	Yes		Yes	Yes	n/a
Uncertainty		Yes	Yes	Yes	n/a

[a] Li et al.[47] [b] Gu et al.[27] (did not cover Gothenburg case) [c] Li and Hensher[21]

5. EVIDENCE FOR EFFECTIVENESS

PHOTO: Guillaume Jaillet, Unsplash

Summary of evidence from this section:

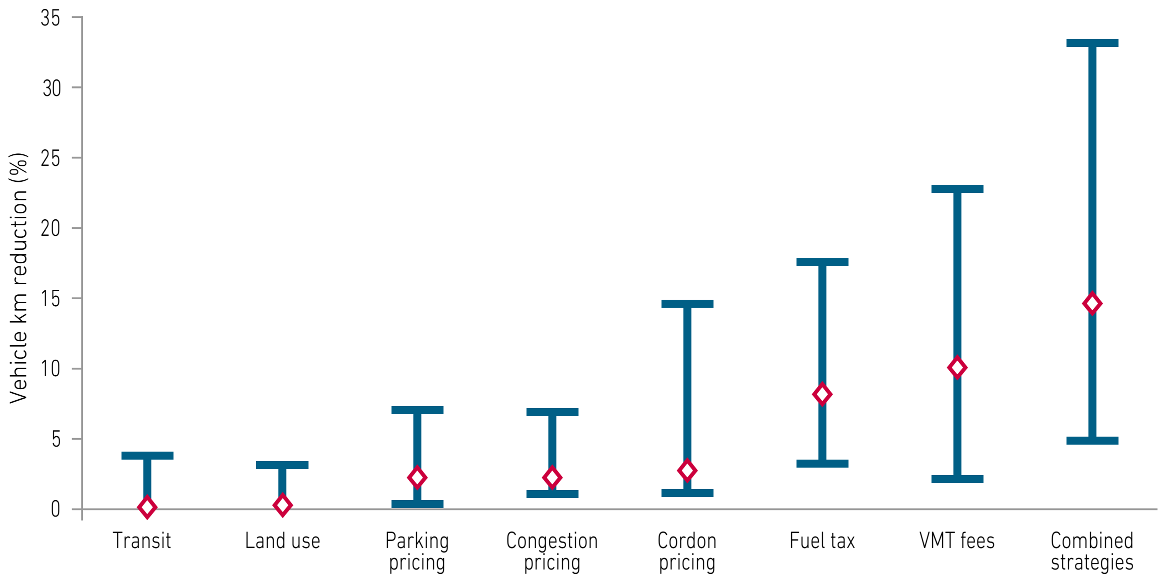
- Stringent road pricing can reduce GHG emissions
- Reductions are likely higher for passenger vehicles than for freight
- Long-term reductions can be larger but are more uncertain
- Road pricing can reduce rebound effects from other policies
- Less is known about ZEV zones, though ZEV exemptions might be an effective design feature for road pricing (unless their impact overlaps with other ZEV sales requirements)

There is clear evidence that road pricing schemes can help a region reduce GHG emissions from road transportation. Carbon pricing (which we consider a form of road pricing) in particular can play a strong role, if the tax is high enough. The High-Level Commission on Carbon Prices indicates that Paris Agreement goals require carbon pricing in the range of US$40 to $80 per tonne CO_2 by 2020, and US$50 to $100 per tonne CO_2 by 2030.[52] However, such pricing is rare; while pricing exists in regions that account for 20 per cent of global GHG emissions, less than five per cent of those are at levels consistent with Paris Agreement goals.[53] This lack of national-level political will is another reason that road pricing might present an option for mitigation by city or metro governments. While Canada has carbon pricing in place, it is not yet strong enough to substantively contribute to the Paris Agreement goals.

For other forms of road pricing, a 2009 U.S.-based systematic review of modelling studies found that a "mixed" strategy of road pricing, improved transit and compact development could reduce VKT in a given year by seven to 23 per cent over 10 years of implementation, and 15 to 26 per cent over 30 years.[5] Comparing the impacts of individual measures (Figure 5), the highest impact was from road pricing, notably VKT-based pricing (five to 22 per cent VKT reductions over 30 years). A more recent systematic review (2018) finds that road-pricing schemes can reduce GHG emissions in a given year by two to 13 per cent.1 As summarized in Table 1, estimates of GHG reductions from empirical case studies range from 2.5 per cent (Gothenburg) to 22 per cent (Milan), and traffic volume reductions range from 10 per cent (Gothenburg) to 44 per cent (Singapore). As noted for the case of Metro Vancouver, the Mobility

Pricing Independent Commission estimated that a modest congestion price could reduce 2030 GHG emissions by two to three per cent relative to the baseline that year, although this illustrative system was designed for congestion relief rather than GHG mitigation.

Figure 5: Summary of potential of different VKT reduction policies (studies over 10-year time frame only, similar to 2030 targets for Metro Vancouver).



Source: DSF report [35] adapted from Rodier (2009)[5]

Effectiveness varies considerably by type of program. Estimates of GHG emissions reductions are in the range of two to 10 per cent for cordon areas, and as high as eight to 13 per cent for VKT-based (or distanced-based) prices, including distance-based insurance, as well as fuel taxes.[1-3] Deeper reductions (15-40 per cent) are theoretically possible in the long term (over several decades), with a much stronger tax,[2,4] and if road pricing is combined with several complementary measures, including greatly improved transit service and active travel infrastructure.[5-7,50] That said, considerably more research is needed to understand the complexities of policy interaction effects, especially in the long term (over decades).[54]

Consumer response to road pricing varies according to a number of factors. For example, the response is higher for those who commute further and have transit as an option.[6] Further, while a great deal of research suggests that consumers undervalue fuel savings,[55] this might not always be the case. In particular, there is evidence that the salience of the pricing mechanism is important; publicly debated pricing policy can have four times the impact on travel patterns as a relatively unknown fuel tax.[56] Further, consumer response is particularly uncertain in the long term,[7] where responses to taxes may be stronger (more elastic) than responses to changes in fuel prices through other means.[3,56,57]

Across studies, it is difficult to assess the broader system impacts. Many studies focus on impacts across the cordon, or in the cordon area, but not on broader impacts for the entire region. Long-term (multi-decadal) impacts are particularly difficult to capture. As one example, implementation of cordon pricing might induce some households to relocate their home or work, perhaps several years later.[21] Housing development and urban design may also change due to the presence of road pricing. Two long-term modelling studies of the U.S. attempt to capture some of these dynamics. They suggest that VKT-based taxes can cut 2040 emissions by around 30 per cent,[2,4] or up to 50 per cent if combined with extreme land use and transit policy (removing private vehicle lanes from 40 per cent of roads, doubling or quadrupling the rate of transit service while eliminating fares).[4]

Most of the above studies indicate that GHG mitigation and travel reduction are more likely among passenger travel rather than freight or commercial vehicles. Freight (tonne km travelled) and commercial travel are found to be relatively inelastic; that is, less responsive to pricing in terms of overall VKT and GHG impacts.[2,10,11] However, a study of a Swiss program indicated that pricing induced more efficient logistics, including less usage of freight trucks, and potentially a stabilizing of VKT (where it was previously growing).[58] More nuanced exploration suggests that different firms may react differently. For example, smaller companies may be more likely to change their routes to avoid a tolled zone.[59] Another study suggests that differentiated tolls – giving exemptions or discounts to more efficient or alternative-fuel drivetrains – can induce improved efficiency in the trucking fleet.[15] Relatedly, for fleet owners (rather than operators), decisions on vehicle purchase can be less sensitive to fuel prices than households, when the fleet vehicles are rented or leased and fuel costs are borne by another entity (i.e., the operators).[10]

More conceptually, several studies also point to the importance of road pricing to mitigate rebound effects from two broad sources. First, while regulations require new vehicles to steadily improve their efficiency each year (e.g., CAFE and other vehicle emissions standards), the resulting lower cost per VKT can have the unintended side effect of inducing more vehicle travel,[60] as well as purchasing of larger vehicles[37]. Road pricing (especially per VKT or unit fuel) can reduce this rebound.[14] Pricing could similarly address rebounds that are expected from new mobility innovations that might reduce travel costs per passenger kilometre, namely ride-hailing, automated vehicles or shared automated vehicles.[8,9,61] Of course, there is a great deal of uncertainty in the future of these innovations, and much more research is needed.

There is little research and experience with ZEV zones. Only a few modelling studies consider ICE bans for GHG goals, and these focus on national or global ICE bans[62,63] rather than city-level bans. More research has looked at the impact of LEV zones on air quality (mostly in EU countries), and results have been mixed – with noticeable reductions in some areas (Germany), and little or no benefit in others.[64] Heavy duty–based LEV zones in particular have had less success in improving air quality.[64] However, consumer-based research suggests that the plan to introduce a city-based ICE ban would increase consumer willingness to buy an electric vehicle.[65] Further, tolling in Milan was successful in shifting vehicle ownership toward alternative-fuel and hybrid vehicles due to exemptions,[66] suggesting that ZEV exemptions or discounts might be an effective design feature of a road pricing policy. We found no studies exploring the interaction with a city-based ZEV zone and a regional or national ZEV sales mandate where, plausibly, the impact of these policies could overlap and provide no additional GHG reductions.

6. EVIDENCE FOR COST-EFFECTIVENESS

Summary of evidence from this section:

- Road pricing is likely to yield a net economic benefit, largely due to congestion alleviation
- Road pricing can improve the efficiency of existing regulations (mitigating rebound effects)
- Less is known about economic impacts for freight

A number of studies consider the economic efficiency or "cost-effectiveness" of road pricing. Common measures include impacts on gross domestic product as an aggregate indicator of economic activity, or more specific measures such as consumer welfare or industry profit. Typically, such studies find a net economic benefit, focusing on congestion impacts, where congestion is seen as a large source of economic inefficiency.[12] Some studies estimate that congestion reduces GDP by one per cent in many North American cities, and by five to 10 per cent in some developing countries.[67] Thus, congestion alleviation is thought to lead to a substantial economic benefit.

To start, we note this stream of research has the same limitations and research gaps as the above effectiveness research – with added uncertainty due to the needed assumptions about how various impacts translate into welfare or GDP. Several key research gaps should be noted. First, model results can be particularly sensitive to assumptions. For example, an earlier study suggested that Stockholm's cordon pricing reduced welfare,[17] while a later, more sophisticated model instead found a positive consumer surplus when accounting for broader system effects and dynamics in behaviour.[12] Second, cost-effectiveness studies tend not to be comprehensive in coverage of benefits, neglecting GHG benefits, as well as many potential co-benefits, such as reductions in air pollution and improved physical health (if pricing increases the share of active travel). An unfortunate consequence of the focus on congestion is that such studies tend to recommend a pricing design that prioritizes congestion reduction over our present focus on GHG mitigation. Finally, there is little attention put toward the costs of actually implementing and operating the road pricing project.[68]

With these caveats in mind, most studies indicate a positive net benefit from pricing. For example, one modelling study finds that pricing can reduce congestion costs by 16 to 27 per cent in Greater Los Angeles.[13] A modelling study based on Stockholm similarly found net social benefits, even in sensitivity analyses that changed transit availability and bypass options. The authors inferred that the positive social results are at least somewhat transferable to other regions.[22] The *Metro Vancouver Mobility Pricing Study* estimated that a congestion pricing scheme could yield net economic benefits to the region of $220 to $290 million per year. As noted above, road or fuel pricing is also found to be an efficient complement to existing efficiency regulations, such as national vehicle emissions standards, largely due to the mitigation of potential rebound effects.[14]

As with other pricing impacts, there is less research focused on economic impacts for heavy-duty vehicles and freight. Policy-makers may be particularly concerned about this sub-sector, where impacts are hard to predict. On the one hand, taxing goods movement could reduce overall economic activity. On the other hand, reducing congestion could improve goods-movement efficiency. The scarcity of research is probably in part due to the added challenges of modelling company behaviour, where decision-making data tend to be proprietary. In one attempt, a study on heavy-duty vehicle tolling finds that there is not a substantial economic impact (a very slight reduction in GDP and employment),[15] which reinforces the above-noted findings that freight activity (overall VKT) is relative inelastic in regard to road pricing.

7. EVIDENCE FOR EQUITY (FAIRNESS)

PHOTO: Unsplash.com

Summary of evidence from this section:

- Equity or fairness is highly impacted by program design
- The equity impacts of a given design can vary by region or context
- Careful design can improve equity

The above-noted studies on aggregate cost-effectiveness (net benefit or cost) typically shed some insight on equity as well – identifying the relative "winners" and "losers" of a given program. Equity is important not only for its own sake (i.e., goals of social justice or equity), but also in that perceptions of inequity are likely to reduce political acceptability (as noted in the next section). Indeed, fairness was raised as a major concern among stakeholders in the *Metro Vancouver Mobility Pricing Study*.

While it seems that road pricing can offer positive net economic or social welfare benefits, it is inevitable that benefits and costs will be unevenly distributed among the population. Following the limitations of studies noted above, results of equity studies vary widely. Pricing can be regressive or progressive (affecting low-income individuals proportionally more/less than higher-income individuals), depending on region, program design and study method.[16]

Two design features can play particularly large roles in equity analyses: the use of tax revenues, and exemptions. In addition to covering pricing system costs, revenues can be used to fund public transit and active transport and road infrastructure, and to reduce a range of taxes that are related or unrelated to transportation (e.g., fuel taxes versus income taxes).

Exemptions to road pricing can apply to specific vehicle types (e.g., motorcycles, school buses), specific activities (e.g., emergency services), and specific groups of people (e.g., residents of a cordon zone, low-income households, particularly vulnerable businesses or those with little access to transit alternatives). Exemptions for ZEVs are likely to favour higher-income households given that they purchase most of these vehicles.[69]

Equity impacts vary considerably by study and context. One study finds that using revenues for tax cuts will provide greater benefits for high-income people, while using revenue for transit improvement will bring a greater benefit to low-income people and women.[17] Another study finds that pricing that does not vary in time will have a worse impact on low-skill, low-income workers.[18] As a particular challenge, one study points out that more efficient road pricing options might be less equitable, and vice versa[19] – though, again, careful design of revenue recycling and exemptions can likely help to mitigate inequitable effects.

To improve fairness and political acceptability, road pricing design should take stakeholder input into consideration, especially from communities that are expected to bear greater burdens and/or fewer benefits. If pricing is applied to freight, research suggests that commercial interests also should be addressed in design of the policy, such as the concerns of small- to medium-sized enterprises regarding heavy-duty vehicle tolls.[15]

8. EVIDENCE FOR POLITICAL ACCEPTABILITY

Summary of evidence from this section:

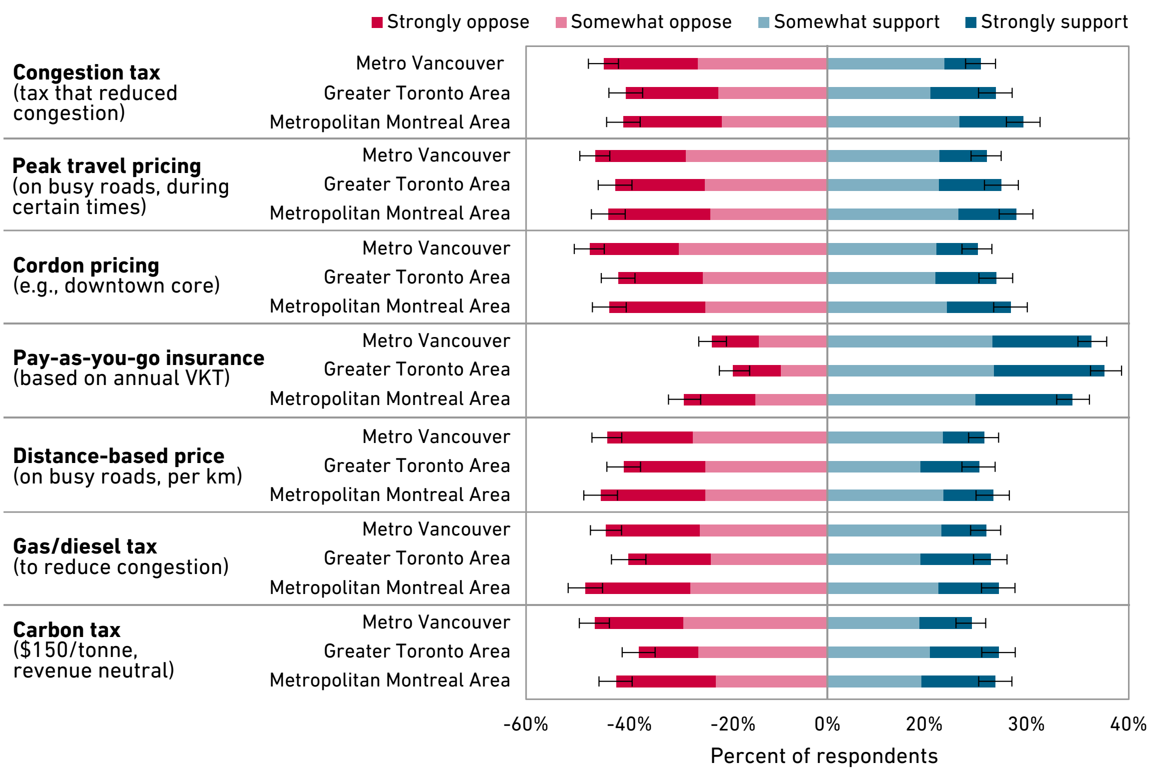
- Public and stakeholder opposition is usually the largest barrier to pricing
- There is more support for pricing policy that is simple, transparent, fair and effective at reducing congestion
- Support largely hinges on trust in the administrator and the implementation process
- ZEV zones are likely to face similar or greater opposition than pricing

The lack of political acceptability is in practice the largest barrier to the implementation of road pricing. Even an effective, efficient and equitable program will not likely be implemented (in most democratic countries) if policy-makers think the program would cause them to lose the next election. For the most part, pricing measures have the most opposition among citizens relative to other climate policies,[20,70-72] and road pricing in particular almost always has low popularity, at least prior to implementation.[21] Serious congestion charging proposals have been declined in several regions, including Edinburgh, Manchester, Helsinki and Copenhagen, when stakeholders were not convinced that pricing is efficient or effective.[22]

Regarding effectiveness and efficiency, many stakeholders assume that traffic patterns will not change and that collected revenue is just a "money grab" by government.[22] Opposition also stems from the inevitable preference for the status quo; most people react negatively to the idea of having to pay for something that was "free" in the past.[23] Other citizen concerns relate to loss of freedom and perceptions of inequity,[25,73,74] or lack of trust in the system.[23]

Citizen support tends to vary by type and design of the road pricing measure,[29] and can be influenced by the framing of the impacts. As an illustration, two recent Canadian surveys (2019 and 2020) collected data on citizen support for and opposition to various pricing schemes (unpublished), comparing representative Canadian samples collected from Metro Vancouver, the Greater Toronto Area and the Metropolitan Montreal Area. Figure 6 depicts that for most pricing schemes (congestion, peak travel, cordon, VKT, gas or carbon tax), there tends to be more opposition than support – with similar trends for each metro region. The one exception is "pay as you go insurance" (based on annual VKT), which received significantly higher acceptance and lower opposition in all three regions (at 99 per cent confidence levels). We suspect that the higher support may have more to do with opposition to status quo mechanisms for auto insurance rather than support for road pricing itself.

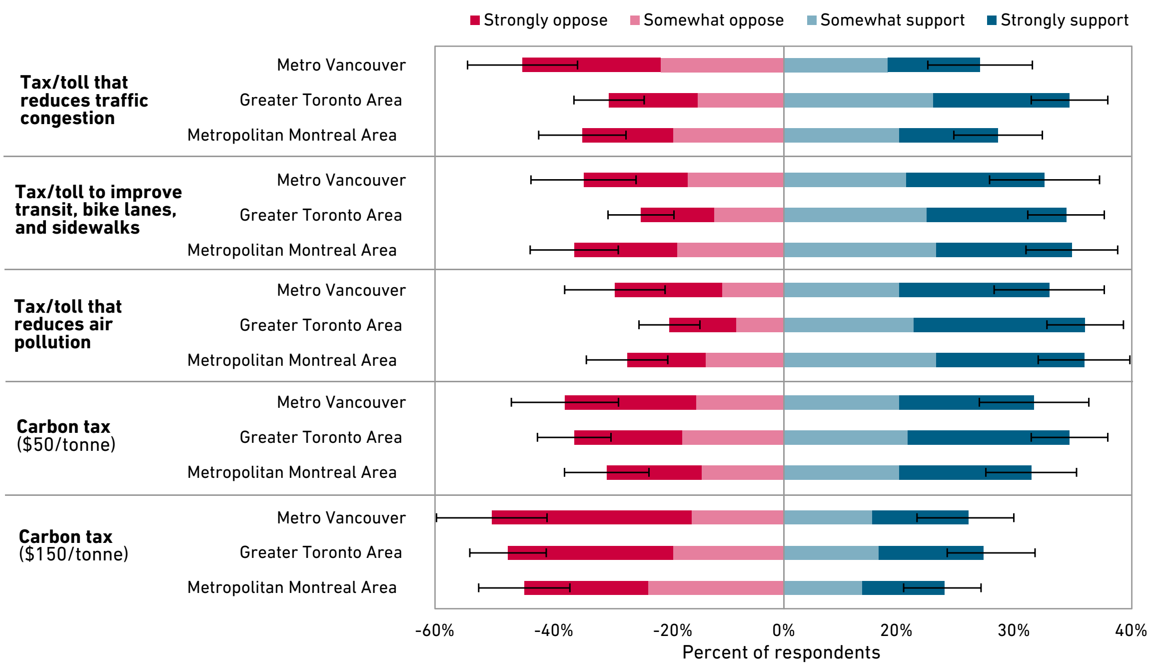
Figure 6: Acceptance by road pricing type



Data collected June 2020; Samples: Metro Vancouver (n = 993), Greater Toronto (n = 794), Metro Montreal (n = 819); Whiskers indicate 95 per cent confidence interval (Source: Axsen and Long, unpublished)

Figure 7 depicts differences in support by policy type and framing, where the benefit of air pollution reduction is slightly more popular than pricing that focuses on congestion relief, investment in active travel or public transit infrastructure, or GHG emissions (although most differences are not significant at a 95 per cent confidence level).

Figure 7: Acceptance by frame



Data collected June 2019; Samples: Metro Vancouver (n = 106), Greater Toronto (n = 221), Metro Montreal (n = 154); whiskers indicate 95 per cent confidence interval (Source: Axsen and Long, unpublished)

The most popular pricing design can vary widely by region and context. The use of tax revenues can be an important factor, though results vary in terms of which uses are more popular in that region.[21] On the other hand, citizens prefer a scheme that is relatively transparent and easy to understand – where time of day, cordon charge or a flat rate per kilometre might be more clear than a variable charge.[21,30] As noted, perceptions of the fairness of the program are important, including the tolling method and compensation scheme,[74,75] as well as any use of exemptions, and overall perceived inequity of incomes across income groups and even across cities.[76]

Support also varies across individuals due to a number of factors such as degree of concern about traffic-related environmental impacts[77] and more general pro-environmental attitudes.[31] Not surprisingly, support varies by perceptions of personal benefits or costs from the program.[75]

Support can also be shaped by communication of the program (such as the usage of revenues[29]), as well as media coverage. Exposure to positive or negative media has been shown to play an important role, especially in shaping perceptions of environmental or congestion impacts,[71] or high implementation costs.[68] A recent study on frames found that the "polluter pays" storyline was most successful among supporters, while several other frames resonated with citizens who opposed the program, including perceived needs for better mode alternatives (improved transit, active travel infrastructure, etc.), and desires for more personal benefits and freedom from government intervention.[34] Other research suggests that support can be improved by focusing communication on pro-social outcomes of the program, including less pollution, improved transit and easier travel for all.[23]

Trust in the government or system is a key theme in successful pricing implementation. A broader study found that stringent carbon prices only exist in regions with high government trust.[72] A road pricing study found trust in the "fairness" of government is crucial for policy support.[78] In this case, the perceived fairness of personal impacts was considered more important than distributional (equity) or procedural fairness.[78]

Relatively less research has focused on support among particular stakeholders or interest groups, which can vary for a given program or context. Opposing political parties will typically debate road pricing, selecting competing frames that serve their own interests.[24] Another challenge is that some city planners and related stakeholders tend to see active travel, public transit and compact development as more important sustainability "solutions," and don't necessarily see road pricing as effective or necessary.[79,80] Among other stakeholders, freight road users can be more opposed to pricing than passenger users[25] – though an exploration of Beijing businesses found a great diversity of responses, with higher support among central businesses, and lower support among large businesses in suburbs.[47] Research in Metro Vancouver suggests that commercial drivers would value improvements in congestion and reliability of journey times, but would want a road pricing system to be transparent to communicate changes in delivery costs to customers.[26]

Little research has explored citizen perceptions of ZEV zones. One U.K. study finds high opposition (60 per cent) to a national ICE ban,[81] though city-based support is higher for a diesel ban.[82] On the other hand, diesel bans have led to an active "pro-diesel" movement in parts of Germany.[83] It is unclear if ZEV zones have more or less support than other road pricing designs, or if the inclusion of exemptions or discounts for ZEVs (or efficient vehicles) would improve acceptability of a given program.

9. EVIDENCE FOR IMPLEMENTATION PROCESS

PHOTO: airfocus, Unsplash

Summary of evidence from this section:

- The implementation process is key in building public and stakeholder support for pricing
- A well-designed trial may help to garner support for pricing, in some cases paired with a post-trial referendum
- Successful implementation processes have carefully addressed concerns about privacy and equity, avoided complexity and reduced uncertainty through effective communication

Given the importance of political acceptability, relatively little research has been done on the policy implementation process. A few studies provide some helpful insights and hypotheses that should be further explored in future research.

In particular, Gu et al.[27] compare the implementation processes of several successful road pricing cases (Singapore, Stockholm, Milan, London) with several strong proposals that were ultimately rejected (New York City, Hong Kong, Edinburgh, Manchester). The authors point to a number of qualitative factors that can improve the odds of implementation. In particular, the study argues for an “interaction-oriented” political process that carefully prioritizes public and stakeholder consultation and information sharing. The authors point out that while a “government-oriented” or unilateral process happened to work for Singapore and London, such an approach is not desirable as a universal template.

Gu et al. identify four different factors that seem important for strong public support, where each successful case study had addressed three of the four factors (noted in Table 1). The “rejected” programs addressed zero or only one factor. The factors largely address some of the themes of political acceptance noted above:

1. **Assuring privacy:** Where some users worry about the use of their personal travel data. For example, Singapore addressed this by removing individual identity information from payment cards.
2. **Equity:** Research repeatedly finds that users want to perceive fairness for themselves and others. As successful examples that improved acceptance, London and Milan gave exemptions to people with disabilities, while Stockholm ended up collecting more fees from higher-income individuals and males. In contrast, the rejected cases did not address equity. Hong Kong's attempt at road pricing included exemptions for taxi and commercial vehicles, which backfired and led to more opposition.
3. **Complexity:** As already noted, a switch toward a more simple, easy-to-understand pricing system seems to help with acceptance.
4. **Uncertainty:** A new pricing program inevitably brings more uncertainty than the status quo. Communication and implementation processes should try to reduce uncertainty about the program and its impacts, especially effectiveness and revenue collection.

To address these factors, Gu et al.[27] recommend an extended three-step, interaction-oriented approach to increase public acceptance (also drawing from [84]). First is using careful, focused communication during the design stage (working with media) to address concerns about privacy, equity and complexity. Second is implementing a trial of road pricing prior to any referendum or decision, which would be a temporary program, potentially implemented on a subset of the region (or users). The authors argue that if such a trial is implemented, it is key to effectively communicate results of the trial to provide certainty and improve understanding of the benefits. Third is to prioritize building and maintaining social trust during the implementation stage, continuing careful consultation with stakeholders and following through with any promises (e.g., revenue allocation).

Some of the studies already cited can provide additional lessons for pricing implementation. For example, in Stockholm, the benefit of building redundant and reliable road-pricing infrastructure is believed to outweigh the additional implementation cost.[68] Building from Gu et al.'s recommendations for communication, the noted research on policy frames is quite important, where success in the change in support in Stockholm (from high opposition to high support) may be due in part to political and public reframing over time.[24]

While Gu et al. point to the success of pricing referendums enacted in Stockholm and Milan, we note that most pricing referenda have been opposed, such as those run in Manchester and Edinburgh.[84] Hensher and Li[84] warn that a referendum might only be appropriate in regions where the debate has "matured" to a state where voters have sufficient awareness and familiarity with the pricing measure in question. Further, a referendum may not fit well with the political or governance culture of a given region. In particular, Metro Vancouver has a long history of consensus-based planning (among the Mayor's Council), and the failure of transit tax referendum in 2015 may have largely been due to the lack any history of such a form of "direct democracy" in the region, in addition to the limited lead time and polarized political debate that ensued.[41] Taking this into consideration, running a trial and referendum runs the risk of the program being rejected.

10. SUMMARY AND GAPS IN KNOWLEDGE

We find substantial evidence that cities can use road pricing to contribute to deep GHG mitigation goals while also contributing to other sustainability and economic goals. However, the ideal design and implementation process will need to vary dramatically by region and context.

We summarize general insights according to our evaluation framework:

1. **Effectiveness:** There is clear evidence that stringent road pricing can make an effective contribution to GHG mitigation in the short and long run, when used to complement an existing policy. This is especially true for passenger vehicles, but more uncertain for freight and heavy-duty vehicles, where more research is needed.
2. **Cost-effectiveness:** There is considerable uncertainty in analyses of welfare impacts, though most studies suggest that road pricing will lead to a net social benefit, with the primary benefit being congestion reduction. Such studies tend not to be comprehensive in their coverage of social benefits, and may overly prioritize congestion goals over GHG or other environmental goals. Seemingly, more comprehensive studies should indicate that road pricing is even more cost-effective than what is suggested by existing literature. There is even more uncertainty about the efficiency of ZEV zones.
3. **Equity:** All pricing programs will affect users differently, which can have important equity impacts. There is evidence that careful design of pricing exemptions and the use of revenues can greatly improve equity (and political acceptability), though the ideal design seems to vary greatly by context. Further, a more equitable design might not be the most cost-effective design.
4. **Political acceptability:** Opposition among citizens and stakeholders is typically the most important barrier to pricing implementation. Citizens tend to oppose pricing mechanisms more than any other climate or energy policy. Improved perceptions of

effectiveness, efficiency and equity can increase acceptability, as well as improved trust – all of which can potentially be achieved through the implementation process (next).

5. **Implementation process:** Success for road pricing is not just about careful policy design, but also the implementation process. This research area is relatively thin, though studies indicate that a number of design principles can serve to build citizen and stakeholder support over time, following an "interaction-oriented" process, including repeated consultation with all relevant stakeholders, clear communication of benefits, consideration of a demonstration phase and ideally agreement among many or most political parties.

There is very little research on ZEV zones and no evidence that they are necessary for GHG mitigation. However, offering ZEV exemptions for road pricing may be an effective design feature. Further research should more carefully compare ZEV zone design with various pricing schemes, in terms of GHG impacts, provision of co-benefits such as congestion and equity, and interaction with broader regional or national ZEV sales requirements.

Table 2 summarizes some of this evidence across the broad categories of: i) cordon or area pricing, ii) VKT/fuel/carbon pricing and iii) ZEV zones or exemptions. Note that these three categories are not mutually exclusive; a road pricing approach could combine two or all three elements.

TABLE 2: Summary of evidence, across different design features (not mutually exclusive design)

	Cordon/area pricing	VKT/fuel/carbon pricing	ZEV zone/ exemptions
Effectiveness			
GHG mitigation	• Moderate potential	• Higher potential	• Unclear (especially with other ZEV policy)
Co-benefits	• Can target congestion • Can manage air pollution hot spots	• Some air pollution relief • Some congestion benefit	• Can manage air pollution hot spots
Cost-effectiveness	• Likely net benefit, with congestion relief	• Likely net benefit, complementing regulations	• Unclear
Equity	• Some inequity impacts (needs careful design)	• Some inequity impacts (needs careful design)	• Some inequity, likely income inequity in particular
Acceptance			
Public	• Significant opposition, with possible growing support if congestion improved	• Significant opposition (more support for VKT-based insurance)	• Probably higher opposition
Commercial/ freight	• Operators might support, with demonstrated congestion relief	• Less likely to support	• Less likely to support
Implementation potential and challenges	• Needs new infrastructure • Needs simple design, clear communication of impacts • Use a trial or not?	• Can work with existing systems (carbon price, fuel tax, insurance)	• Same as cordon area

We have also identified a number of important research needs in our review:

- More research on the long-term GHG benefits of road pricing (rather than congestion or short-term impacts only).
- More sophisticated modelling of long-term impacts, including simulation of travel behaviour in short and long term, namely daily mode choice, as well as vehicle ownership, vehicle purchase choice and residence and workplace choices.
- More study of how pricing schemes and ZEV zones affect technology development in the long run, namely for programs that provide exemptions or discounts for more efficient or lower-carbon vehicles. Such programs could increase consumer demand for such vehicles, and stimulate technology learning and other aspects of transformative change.[54,85]
- Because of the "hype" and interest around ICE bans and ZEV zones, more careful research is needed on the effectiveness, efficiency, equity and acceptability of such designs, including integration of ZEV exemptions into road pricing schemes.
- Pricing studies need to better follow a "policy mix" perspective, modelling interactions of pricing mechanisms with regulations, incentives, infrastructure deployment (for transit, active travel and ZEVs) and other policy types. Initial attempts suggest that pricing can generally complement other climate and environmental policies, though more nuanced exploration is needed.
- In particular, research could explore the potential role of road pricing to induce GHG mitigation in the short to near term, while high-impact regulations (ZEV mandate and vehicle emissions standards) tend to require decades to realize substantial mitigation.
- Greater study of other mechanisms such as parking prices (and availability of parking) that can be integrated into a pricing strategy.
- Exploration of "tradeable permit" schemes for commuting, which could potentially improve acceptability, if policy-makers could overcome complexity.
- More careful explanation of impacts for heavy-duty vehicles and freight, including optimal design (if feasible) for GHG impacts, efficiency and acceptability among freight and other heavy-duty stakeholders.
- More exploration of pricing design relating to new mobility innovations, especially ride-hailing (individual and pooled), car-sharing and automated vehicles, and combinations thereof. As examples, pricing can be designed to try to reduce VKT from such modes, such as offering exemptions for "pooling," and charging higher costs for empty travel or "dead-heading."

11. KEY CONSIDERATIONS FOR ROAD PRICING DESIGN AND IMPLEMENTATION

PHOTO: Mick Baker, CC BY-ND 2.0

From this available evidence, we identify four broad categories of considerations and discussion points important to developing a road pricing policy, including one that would apply to Metro Vancouver or Montreal. We limit our considerations to broader concepts, although many specific details should be determined for a particular program, including geographic scale, type of fees (dynamic versus flat rates) and technology type for administering fees. Specific details will have to be determined for each region on a case-by-case basis.

First is the overall type of road pricing. Climate benefits are maximized with a strong fuel tax or per VKT fee and should be pursued if politically possible. Area- or cordon-based approaches offer a more flexible approach that can also manage congestion and air pollution hot spots. An area- or cordon-based approach should be kept simple, using flat fees during daytime, for example, as this tends to be more acceptable to the public and follows the approaches used by successful examples in London and Stockholm. Finally, a full ban of higher-emitting vehicles in a given region seems likely to provoke particularly strong opposition when benefits are unclear due to limited research. ZEV/LEV adoption might be better supported through exemptions from road pricing, although even the impact of this action is unclear in regions that already have a strong ZEV sales mandate.

Second is the use of revenues, which can highly affect the equity impacts, perceived fairness and overall acceptability of the pricing plan. Investment in transit and active travel will certainly complement the climate (and congestion) benefits of road pricing. However, acceptability can be boosted with some amount of road improvement and/or tax cuts as well (that is, cuts to income tax, corporate tax or goods and services taxes). Further, some amount of revenue could be used as rebates or credits for those unfairly affected by the tax, such as low-income households or households in areas with relatively little transit service.

Third is the specification of exemptions. For equity impacts, regions should include exemptions for people with disabilities, as well as emergency vehicles. Some commercial vehicles could be considered for exemption. The case of freight is more complicated. Although freight exemptions are attractive (at least to boost political acceptability), freight transportation is a major source of air pollution and GHG emissions. Further exemptions could be considered for various strategic purposes that line up with sustainability goals, such as "pooled" ride-hailing vehicle trips (where multiple strangers are matched into a single, streamlined trip — e.g., Uber Pool). As noted, pricing could be reduced or fully removed for passenger and freight ZEVs, or even for smaller or more energy-efficient vehicles (LEVs), which can potentially support adoption of such vehicles in the long run. Again, that impact is unclear when a region already has a strong ZEV sales mandate.

Fourth is the implementation and consultation process. Program design and overall implementation should prioritize building support among as many stakeholders as possible (and ideally, also among multiple political parties). Clear benefits should be offered for drivers (reduced congestion), transit users (better services), businesses (improved traffic flow, perhaps exemptions for their vehicles) and negatively impacted sub-groups (e.g., compensation credits/rebates). Other regions have had some success with a program that includes one or more demonstration/trial and referendum phase (in that order), to effectively try out the pricing policy before committing. However, a referendum might not fit with the political or governance culture of a given region, such as Metro Vancouver, which has more experience with consensus-building among regional mayors and little history with direct democracy (i.e., referenda) on matters of transportation. In this case, a referendum also brings the risk of the region having to eventually abandon a program (if voted down) after substantial investment in the trial. Relatedly, the pricing scheme needs to be communicated and framed in a way that best resonates with the region, effectively building trust in the policy administrator and program more generally. The literature offers examples and general guidelines for communication, though a program really needs to be customized to the unique context of a given region.

12. RECOMMENDATIONS FOR METRO VANCOUVER AND MONTREAL

PHOTO: Paul Krueger, CC BY 2.0

As a final component to this report, we consider how the insights from this broad evidence base may suggest specific recommendations for Metro Vancouver and Montreal in achieving 2030 and 2050 GHG mitigation goals.

Most centrally, we recommend that these regions implement road pricing among their leading mechanisms to reduce GHG emissions from road transportation. Our specific recommendations are based on the key considerations noted above. They are listed in Table 3.

We again recommend that road pricing be viewed as part of the broader mix of transport and climate policies. Many of the policies and strategies noted in our 2019 *Shifting Gears* report[35] will be important complements to a road pricing strategy, including continuation of strong provincial/national level regulations (vehicle emissions standards, low-carbon fuel standards and ZEV sales mandate) and carbon pricing. Further, metro regions and cities will want to support active travel, public transit and improved quality of the built environment (including density, diversity and transit-oriented development).

Finally, we note that road pricing design should take a long-term view, anticipating and complementing new forms of mobility. In particular, road pricing can be one of the most effective ways to responsibly guide the rollout of car-sharing, ride-hailing and vehicle automation technologies, to assure they lead to substantial GHG reductions and avoid rebound effects from cheaper travel modes.

TABLE 3: Summary of recommendations

Design consideration	Recommendations	Considerations and alternative actions
Type of pricing	• Strong enough price to have significant traffic impact • Keep it simple • Pursue carbon/fuel/VKT tax for maximum GHG benefit • Also consider cordon pricing, using natural boundaries (waterways), with simple time structure (e.g., daytime)	• Carbon/fuel taxes can build off existing systems • Price per km (VKT) is more challenging to implement and explain • ZEV zone could be effective, but probably less acceptable
Use of revenues	• Make strategy transparent • Address stakeholder concerns • Probably a mix of allocation to program costs, public transit, active travel, roads, as well as stakeholder credits and/or tax cuts	• Customize based on regional consultation • Assure that strategy still supports GHG reductions
Exemptions	• Provide exemptions for people with disabilities and emergency vehicles • Carefully consider other exemptions; e.g., residents within cordon area or commercial vehicles • Consider exemptions for pooled vehicles and pooled ride-hailing	• Don't exempt too much, or the policy won't work • Charges should ideally apply to most or all commercial and freight vehicles • Unclear if ZEV/LEV exemptions will have an impact in regions with ZEV sales mandate
Implementation process	• Implement with intentional strategy, in stages with careful policy framing • Include clear consultation/ communication stages with two-way information sharing • Consider a trial of some sort • A post-trial referendum might work in some cases, but only if it fits with governance culture • Monitor and report costs and benefits (even after implementation)	• Avoid excessive delays • Avoid changes that dilute policy strength • Carefully select any trial period (if at all) • Referendum is risky but can add legitimacy

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