Prospects for Urban Road Pricing in Canada

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When it opened to traffic in 1997, Highway 407 in Toronto became the world's first all-electronic, barrier-free toll highway, charging tolls based on vehicle type, distance driven, time of day, and day of week. But no comparable highways have been established in Canada since then. Of the 415,600 lane-kilometers of paved public roads in Canada, only 385 kilometers are tolled.[1] Except on Highway 407, the tolls do not vary over time, and no area-based road-pricing scheme exists. Moreover, Highway 407 is privately owned and operated. Road pricing as a tool for internalizing congestion or other traffic-related externalities has therefore not proceeded far in Canada, which lags behind the United States and a number of countries in Europe and Asia with respect to pricing.

This paper assesses the prospects for urban road pricing in Canada, focusing on the role of road pricing for congestion relief rather than environmental benefits or revenue generation, although revenue generation is given some attention.[2]

Because congestion pricing has not been implemented anywhere in Canada and detailed plans have not been developed for any city, the possibilities are relatively wide open.

The concept of an optimal implementation path for road pricing has been discussed in the literature, but no general and comprehensive rules have yet been established and it is clear that prescriptions must be tailored to city-specific circumstances and opportunities. Not surprisingly, the case for urban road pricing appears to be strongest in Canada's three largest cities: Toronto,

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1. Transport Canada (2006a, table 7-1).

2. Lindsey (2007) reviews worldwide experience with road pricing and derives some lessons for Canada. This paper undertakes a more detailed economic analysis of road pricing in individual cities.

Montréal, and Vancouver. The cities differ in topography, freight transport challenges, and road construction plans. Rather than attempting to identify the best scheme for each city—which would call for a detailed cost-benefit analysis of alternatives—this paper entertains a different type of scheme for each city and considers its merits.

Road Pricing and Infrastructure Funding in Canada

Table 1 lists the nineteen existing tolled facilities in Canada (the list excludes facilities under construction for which tolls are planned). Twelve are bridges or tunnels linking Ontario and the United States. Some, such as the Coquihalla highway in British Columbia (BC), are public; others, including Highway 407, are private. All facilities differentiate tolls according to vehicle type; electronic tolling has been implemented on six of the facilities. Some offer discounts to commuters. Highway 407 gives discounts for both light and heavy vehicles depending on usage. Highway 407, the only facility that tolls by time of day, accounts for nearly three-quarters of total annual traffic for facilities with available traffic statistics.

Two limitations of road pricing in Canada are apparent from table 1. First, very little of the road network is tolled at all. Second, existing tolls bear little resemblance to Pigouvian taxes for internalizing congestion externalities, which—as discussed later—are considerable in the three largest Canadian cities. Time differentiation on Highway 407 is limited to a small peak/off-peak differential of about 5 percent.[3] No facility employs dynamic tolling using real-time information such as on the I-10 and I-394 high-occupancy toll (HOT) lanes in the United States. Discounts for frequent users are inconsistent with marginal social cost pricing. Commuter discounts can be justified theoretically as a second-best adjustment to labor market distortions, but it is doubtful that the existing discounts accurately reflect any such distortions.[4]

Tolls on Highway 407 have been controversial since the highway was purchased in 1999 by 407 ETR Concession Company Limited. A major reason for building the highway (and also a requirement in the existing concession agree-

3. The tolls are proportional to distance traveled. On February 1, 2008, a distinction was introduced between a regular zone and a light zone, with a slightly higher charge per kilometer in the regular zone during peak periods. According to the operator, the revised policy was implemented to help maintain smooth traffic flows. "407 ETR Announces 2008 Rate Schedule," Toronto, December 28, 2007 (www.407etr.com/About/news/medianews.asp?file=news200719.ini&year=2007 [April 2008]).

4. Parry and Bento (2001).

ment) was to divert traffic from alternative surface streets and from the very heavily congested Highway 401, which runs roughly parallel a few kilometers away. Trucking companies allege that congestion on Highway 401 has not been relieved to the extent anticipated because truck tolls are too high.[5] Tolls are not regulated, but the company is subject to financial penalties if it fails to meet the annual traffic thresholds specified in the contract. Highway 407 usually operates at design speeds throughout the day. It is difficult to tell whether free-flowing traffic and the nominal difference between peak and off-peak toll rates are a consequence of the traffic thresholds or of profit maximization. It also is unclear how much the toll schedule differs from the second-best optimal schedule.[6]

In 2006, C$423 million in revenues was collected from the tolled facilities in table 1. That was just 0.4 percent of total personal expenditures on motor vehicles;[7] the percentages of total revenues collected from drivers and of expenditures on roads were similar. Revenues from users are derived mainly from federal and provincial fuel taxes and the balance from various vehicle and driver licenses and fees. Canada does not have a formal mechanism similar to the U.S. Highway Trust Fund for funding roads or public transportation, and most revenues are not earmarked but consolidated with other taxes in the general fund. Only about 7 percent of federal fuel tax revenues are spent on roads and highways.

As in the United States, much of the road infrastructure in Canada is in disrepair and approaching the end of its design life. There is concern about an unfunded transportation "infrastructure gap" that is expected to grow as increasing vehicle fuel economy erodes fuel tax revenues. To help fill the gap, several federal highway infrastructure funds totaling several billion dollars have been established.[8] The March 2007 federal budget included new infrastructure programs with a total federal contribution of C$33 billion between 2007 and 2014.[9]

5. Colle (2006). Heavy single-unit vehicles pay twice as much per kilometer as do cars, and heavy multiple-unit vehicles pay three times as much. Minimum trip toll charges apply for both heavy vehicle types but not for cars. In response to criticism of high tolls, 407 ETR reached a settlement with the government of Ontario in 2006 that requires it to provide discounts to frequent users.

6. To the best of my knowledge, efficient tolls for Highway 407 have never been estimated. Before the highway opened, Mekky used the EMME/2 software to simulate the effects of different toll rates on travel times, route diversion, and toll revenues. He held total numbers of trips and mode choice fixed and did not evaluate the welfare effects of tolling (Mekky 1995). To the extent that Highway 401 and alternative surface streets are underpriced, second-best tolls on Highway 407 should be set below Pigouvian (first-best) levels. However, insofar as users drive on congested links before and after taking Highway 407, second-best pricing calls for tolls above the first best.

7. Transport Canada (2006b, table A2-66).

8. These are the Strategic Highway Infrastructure Program, the Canada Strategic Infrastructure Fund, the Border Infrastructure Fund, and the Municipal Rural Infrastructure Fund.

9. Department of Finance, Budget 2007 (www.budget.gc.ca/2007/bp/bpc5be.html [May 2008]).

Table 1. Tolled Facilities in Canada

Facility	*Annual traffic (number of vehicles)*	*Operator*	*Toll rates for cars (cash unless otherwise noted)*
Prince Edward Island			
1. Confederation Bridge	Confidential	Strait Crossing Development Inc.	Cash, transponder, and other payment methods: C$41.50
Nova Scotia			
2. A. Murray MacKay Bridge	n.a.	Halifax-Dartmouth Bridge Commission	Cash: US$0.75 Token or MACPASS: US$0.60
3. Angus L. Macdonald Bridge	n.a.	Halifax-Dartmouth Bridge Commission	Cash: US$0.75 Token or MACPASS: US$0.60
4. Cobequid Pass/Highway 104 Toll Highway	2,888,000 (fiscal year 2004–05)	Atlantic Highways Management Corporation Ltd.	Cash: C$4.00 Electronic: C$2.00
New Brunswick			
5. Saint John Harbour Bridge	9,334,000 (1999)	Saint John Harbour Bridge Authority	Cash: C$0.50 Transponder: C$0.30
Ontario			
6. Highway 407	106.8 million (2006)	407 ETR Concession Company Ltd.	Transponder or video[a] Peak weekdays[b] 19.25¢/kilometer in regular zone 19.00¢/kilometer in light zone Off-peak weekdays,[c] weekends, and holidays 18.0¢/kilometer
7. Ambassador Bridge	n.a.	Canadian Transit Company	C$4.00 Transponders available; commuter discounts
8. Blue Water Bridge	5,331,751, both directions (2006)	Blue Water Bridge Authority	C$2.75
9. Detroit-Windsor Tunnel	2,644,213 (2007)	Detroit Windsor Tunnel LLC	Windsor to Detroit: C$3.75 Detroit to Windsor: C$4.75 Discount for tokens

10. Lewiston-Queenston Bridge	2,204,205 (2006)	Niagara Falls Bridge Commission	US$3.25/C$3.25 Discount for tokens
11. Ogdensburg-Prescott Bridge	516,409 (1999)	Ogdensburg Bridge and Port Authority	US$2.75 Commuter and truck charge rebates
12. Peace Bridge	6,623,693 Cars and trucks, both directions (2007)	Buffalo and Fort Erie Public Bridge Authority	Cash: C$3.00/US$3.00 E-ZPass: US$2.70
13. Rainbow Bridge	1,588,364 (2006)	Niagara Falls Bridge Commission	Cash: US$3.25/C$3.25 Discount for tokens
14. Sault Ste. Marie International Bridge	1,915,512 (2007)	Joint International Bridge Authority	US$2.00/C$2.20 Discounts for users of proximity cards
15. Seaway International Bridge, North Channel Span	n.a.	Seaway International Bridge Corporation Ltd.	Cash: US$3.25/C$3.25 Debit card: US$2.93
16. Seaway International Bridge, South Channel Span	n.a.	Seaway International Bridge Corporation Ltd.	Cash: US$3.25/C$3.25 Debit card: US$2.93
17. Thousand Islands Bridge System	2,041,138 (2006)	Thousand Islands Bridge Authority	US$2.50/C$2.50 Discounts for commuters
18. Whirlpool Rapids Bridge (reserved for subscribers to NEXUS, a preapproved clearance program)	89,009 (2006)	Niagara Falls Bridge Commission	US$3.25/C$3.25 Discount for tokens
British Columbia			
19. Coquihalla Highway	3.595 million (2006)	British Columbia Government, TOLLCOQ–Coquihalla Toll Plaza	Cash and credit card: C$10

Sources: All as of March 2008: (1) www.confederationbridge.com/; (2) www.hdbc.ca/index.asp; (3) www.hdbc.ca/index.asp; (4) www.highway104.ns.ca; (5) www.saintjohnharbourbridge.com/; (6) www.407etr.com; (7) www.ambassadorbridge.com; (8) www.bwba.org; (9) www.dwtunnel.com/traffic.html; (10) niagarafallsbridges.com/index.php3; (11) www.ogdensport.com/bridge.html and www.tc.gc.ca/programs/surface/bridges/ogdensburg.htm; (12) www.peacebridge.com/index.php; (13) niagarafallsbridges.com/index.php3; (14) www.michigan.gov/mdot/0,1607,7-151-9618_48384---,00.html; (15) www.sibc.ca/toll/toll_e.html; (16) www.sibc.ca/toll/toll_e.html; (17) www.tibridge.com/ and ibtta.org/Membership/Directory/TICFacilityPro.cfm?OrganizationID=27556&FacilityID=173; (18) niagarafallsbridges.com/index.php3; (19) www.bchighway.com/coqrates/ and www.th.gov.bc.ca/trafficData/tradas/tradas.asp?loc=P-17-8NS.

a. Transponder-recorded vehicles pay C$2.15/month; video-recorded vehicles pay C$3.50 extra per trip. Rates effective as of February 1, 2008.

b. 6:00 a.m. to 10:00 a.m. (morning) and 3:00 p.m. to 7:00 p.m.(evening).

c. 10:00 a.m. to 3:00 p.m. (morning) and 7:00 p.m. to 6:00 a.m. (evening).

In 2005, the federal government introduced a degree of earmarking for fuel tax revenues by establishing a five-year transfer from the Gas Tax Fund to municipal governments to be used for road and mass transit projects. The transfer was made permanent in the February 2008 federal budget. Some provinces also earmark a portion of provincial fuel tax revenues. These initiatives have helped to supplement traditional revenue sources for road and urban public transportation infrastructure, but some are temporary and grants are susceptible to incentive and accountability problems.[10] In addition, funding partnerships between different levels of government are vulnerable to political disagreements.

Road pricing in Canada not only would help to alleviate congestion and other traffic-generated externalities but also would provide a new source of revenues that could be used either to fund more road and public transportation projects or to reduce reliance on traditional, distortionary, sources. Estimates of the excess burden of taxes in Canada as measured by the marginal cost of public funds (MCPF) vary by type of tax as well as by province. Dahlby calculated the MCPF for the personal income tax. For 1986, his estimates ranged from 1.38 in British Columbia to 1.78 in Quebec, with a provincial average of 1.55. For 1993, his estimates ranged from 1.40 in Alberta to 1.99 in Quebec, with an average of 1.66. Dahlby noted that his calculations ignored some factors that bias his estimates downward.[11] In a more recent study, Dahlby and Ferede (2007), the authors used a growth model to determine the long-run burden of taxes in BC. For the personal income tax, they obtained an estimated MCPF of 1.95 using a 10 percent discount rate and of 3.22 using a 4 percent discount rate. Their estimated MCPF for the provincial sales tax is just 0.82. But for the corporate income tax, they determined that the present value of tax revenues declines with the tax rate, so that the MCPF is undefined.

These varied results suggest that the allocation of toll revenues could have significant efficiency consequences and, further, that road pricing could yield a double dividend through the revenues generated. In sum, there is a strong case to consider road pricing in Canadian cities, both as a tool for addressing congestion and as a user-paid source of funds for roads and public transportation.

Legal Powers

Although the federal government levies a fuel tax, facilitates interurban freight transport, and plays other important national roles in road transportation, it does not have jurisdiction over roads, except for highways traversing national parks and a section of the Alaska Highway.[12] Provincial highways are

10. Kitchen (2006); Mintz and Roberts (2006).
11. Dahlby (1994).
12. Clarkin (2007).

controlled by the provinces and municipal roads by cities and municipalities. Any form of road pricing would have to be initiated by provincial and lower levels of governments and their agencies. Cities are generally in a weaker position than the provinces as far as launching a road-pricing scheme because they do not have the legal power to introduce tolls or other new charges. However, the urban transportation agencies in Toronto, Montréal, and Vancouver do have limited powers for charging.

Studies

Transportation policy in Canada has been reviewed in three major federal studies: the Royal Commission on National Passenger Transportation (1992), the National Transportation Act Review Commission (1993), and the Canada Transportation Act Review (2001). Those studies generally supported the "user pays" principle and inclusion of environmental costs in transport pricing. In 2003, the federal government conducted a study of the full social costs of transportation[13] and described a vision for future transportation in which user prices better reflect those costs.[14] However, the federal government has not established a research program for road pricing analogous to the U.S. Value Pricing Pilot Program or a counterpart to the National Strategy to Reduce Congestion on America's Transportation Network.[15]

Recent interest in and support for road pricing in Canada is nevertheless evident at various levels. The city of Vancouver has reviewed alternative approaches for tolling roads.[16] The city of Montréal's transportation plan identifies the possibility of a cordon toll. And both Toronto's urban transportation agency, Metrolinx, and a fiscal review panel for the city of Toronto have recommended study of tolls on 400-level provincial and selected municipal highways.[17] Several recent scholarly articles support the idea of tolling.[18] And the Victoria Transport Policy Institute devotes a section of its website to a favorable assessment of road pricing.[19]

13. Transport Canada (2003a).

14. Transport Canada (2003b).

15. U.S. Department of Transportation, Federal Highway Administration, Value Pricing Pilot Program (http://ops.fhwa.dot.gov/tolling_pricing/value_pricing/index.htm [May 2008]); U.S. Department of Transportation, "National Strategy to Reduce Congestion on America's Transportation Network," May 2006 (http://isddc.dot.gov/OLPFiles/OST/012988.pdf [May 2008]).

16. Greater Vancouver Regional District (2007a).

17. Metrolinx (2008); City of Toronto (2008).

18. Brown and others (2005); Kitchen (2006, 2008); Soberman and others (2006); Conference Board of Canada (2007); Laberge (2007); Lindsey (2007).

19. Victoria Transport Policy Institute, "Congestion Pricing, Value Pricing, Toll Roads, and HOT Lanes," July 17, 2008 (www.vtpi.org/tdm/tdm35.htm [May 2008]).

Public Attitudes in Canada toward Road Pricing

The limited evidence on Canadian attitudes toward tolls is mixed. A 1992 Ontario Ministry of Transportation discussion paper prepared while Highway 407 was under consideration reported results of surveys indicating that tolls would be acceptable if they were dedicated to funding the tolled facility, if the facility would not otherwise be built, and if a free alternative would be available.[20] Highway 407 is heavily used today (more than 350,000 trips are made on an average workday) although, as noted above, there has been discontent with toll levels. As discussed later in the chapter, there is evidence of growing support for tolls, at least if the revenues are earmarked for transportation.

Tolls also have been strongly opposed in Canada. A prominent example is the Fredericton-Moncton Highway project. In January 1998, the New Brunswick government engaged a contractor in a public-private partnership to design, finance, build, operate, and maintain the highway for twenty-five years and to toll a preexisting toll-free section. Had the highway been completed and tolled throughout its length, it would have been the longest toll highway in Canada. But public resistance to the toll developed and contributed to the downfall of the provincial government. Under the new government, the contract was revised to compensate the contractor with shadow tolls, and in March 2000, toll collection ended.

Another example is a 2003 plan to privatize the Coquihalla highway, which has operated as a public toll road since 1986. The BC government backed down from the plan in the face of massive opposition. Both these experiences are with interurban highways, and they may not be indicative of attitudes toward urban road pricing. But they suggest resistance to tolling existing toll-free roads as well as to large increases in tolls. It is noteworthy that all recently completed and planned toll projects in Canada involve newly constructed facilities.[21]

Travel Conditions in Major Canadian Cities

The case for urban road pricing as a Pigouvian tax rests on two conditions: severe traffic-related externalities and adequate scope for motorists to modify their travel decisions. Two primary considerations are traffic congestion and the availability of urban public transport as an alternative to driving.

20. Mylvaganam and Borins (2004, p. 15).

21. Much road infrastructure in Canada is in disrepair and tolls might be introduced on roads after reconstruction or major rehabilitation. The public may not view upkeep of existing infrastructure and new capacity in the same way.

The Texas Transportation Institute's annual *Urban Mobility Report* reveals how congestion delays are changing in U.S. cities. No comparable series exists for Canada. The only comprehensive estimates of the costs of traffic congestion for passenger transportation in Canada were compiled in a study by Transport Canada.[22] Travel demand forecasting models for the nine largest urban areas were used to quantify the costs of travel delay, additional fuel consumption, and greenhouse gas emissions caused by congestion.[23] To measure travel delay, the study adopted a percentage of the speed limit as a baseline below which congestion could be considered "unacceptable."[24] Since that threshold may differ by city, calculations were done using 50 percent, 60 percent, and 70 percent thresholds.

With the 60 percent threshold, the estimated total cost for the nine urban areas is about C$3 billion (table 2). Travel delays account for 90 percent of the total, additional fuel consumption for 7 percent, and greenhouse gas emissions for 3 percent. The annual cost per capita is C$271 for Toronto, C$260 for Vancouver, and C$249 for Montréal. For the six smaller cities, the costs are much lower. These calculations exclude the costs of accidents, noise, local emissions, road damage, and behavioral adaptations to congestion; they also exclude vehicle operating costs other than fuel, freight transport, off-peak congestion, and nonrecurrent congestion. Moreover, they would be higher if free-flow conditions rather than a fraction of the speed limit were used as the baseline. The figures therefore probably understate the true cost significantly. However, because even comprehensive congestion pricing would not eliminate congestion, the estimates in table 2 could be larger or smaller than the potential benefit from congestion pricing.

No study comparable to Transport Canada's has been undertaken of the costs of freight congestion in Canada, which are likely to be considerable.[25] The greater Toronto area produces more than half of Canada's manufactured goods, and about three-quarters of the total value of Canadian exports to the United

22. Transport Canada (2006c).

23. The unit values for travel delay vary by city and trip purpose. For work and work-related trips they range from C$24.71 per hour to C$31.35 per hour; for non–work related trips, they vary from C$7.63 to C$9.67 per hour (in 2002 C$). The costs of additional fuel consumption were calculated using estimates of fuel consumption as a function of vehicle speed and the price of regular unleaded gasoline in each urban area. Greenhouse gas emissions were valued at C$29.97 per metric ton (1998 Canadian dollars).

24. Free-flow conditions are used as a baseline by the Texas Transportation Institute and other studies, but they have been criticized as misleading—see, for example, Waters and von Warburg (2005).

25. Most freight transport is undertaken by the private sector, and publicly available data on freight flows is limited (Metrolinx 2008).

Table 2. Total Annual Costs of Congestion in Selected Canadian Cities
2002 Canadian dollars (millions)

Urban area (2001 population)	*Year*	*Fifty percent threshold*	*Sixty percent threshold*	*Seventy percent Threshold*	*Annual cost per capita at 60 percent threshold*
Toronto (4,682,897)	2001	889.6	1,267.3	1,631.7	271
Montréal (3,426,350)	1998	701.9	854.0	986.9	249
Vancouver (1,986,965)	2003	402.8	516.8	628.7	260
Ottawa-Gatineau (all) (1,063,664)	1995	39.6	61.5	88.6	58
Calgary (951,395)	2001	94.6	112.4	121.4	118
Edmonton (937,845)	2000	49.4	62.1	74.1	66
Québec City (682,757)	2001	37.5	52.3	68.4	77
Winnipeg (671,274)	1992	48.4	77.2	104.0	115
Hamilton (all) (662,401)	2001	6.6	11.3	16.9	17
Total		2,270.2	3,015.0	3,720.6	

Source: Lindsey (2007). Compiled from Transport Canada (2006c, table 5) and Statistics Canada, "Population and Dwelling Counts for Census Metropolitan Areas and Census Agglomerations, 2001 and 1996 Censuses." (www12.statcan.ca/english/census01/products/standard/popdwell/Table-CMA-N.cfm [January 2007].

States cross the border in Ontario, primarily by road.[26] Montréal and Vancouver are major maritime freight gateways, and truck volumes to and from the United States are heavy. Nationwide, freight shipments are concentrated along a few widely separated corridors so that substitution possibilities are limited in the event of weather-related or other disruptions.

Public transportation that offers a viable alternative to driving is often regarded as essential on both efficiency and acceptability grounds for area-based road-pricing schemes. A rough indication of the availability and quality of public transportation is the share of morning commuting trips taken by public transit. Of the nine largest cities listed in table 2, the share in 2001 was highest for Toronto (22.4 percent) and Montréal (21.7 percent), which ranked first and third in congestion costs per capita.[27] Vancouver, with the second-highest congestion cost per capita, has a much smaller public transit share, of 11.5 percent. These shares are far smaller than in London, Stockholm, or Singapore where area-based pricing has been implemented. However, Toronto, Montréal, and Vancouver all have ambitious public transit investment plans to improve service. All the required funding has not been secured, and toll revenues could help fill the gap.

26. According to the Ontario Chamber of Commerce, delays at the U.S. border cost Ontario more than C$5 billion a year (Ontario Ministry of Public Infrastructure Renewal 2005).

27. Statistics Canada, 2001 Census, Mode of Transportation (www12.statcan.ca/english/census01 [December 2006]).

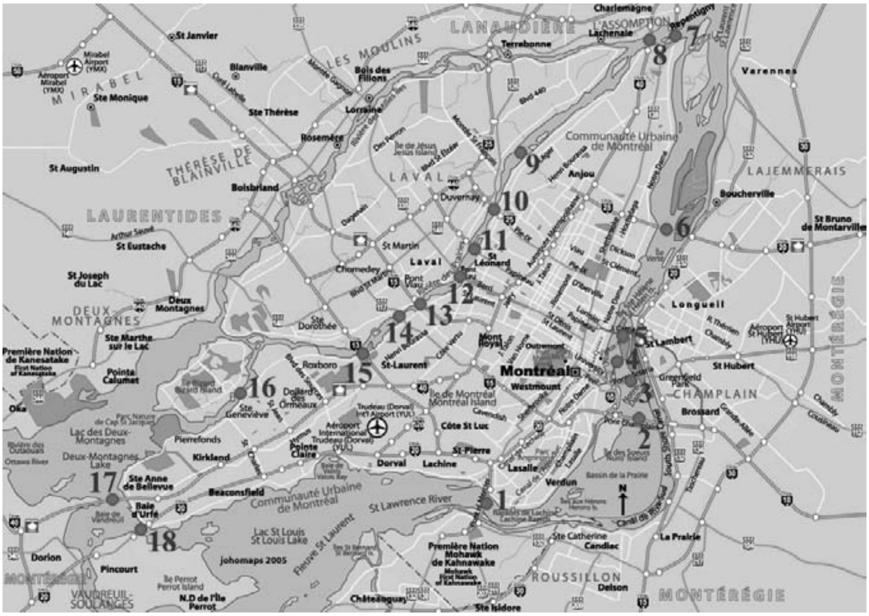
According to Transport Canada's study, Toronto, Montréal, and Vancouver suffer by far the highest costs related to traffic congestion for passenger transportation in Canada, both in total and per capita terms. Freight transport in the cities also poses serious challenges. The three cities have a pressing need for additional revenues to fund construction and maintenance of roads and public transportation. All three have urban transportation agencies with some powers to levy tolls and other auto user fees, and all three will soon have at least one tolled facility, which may help to convince politicians and the public of the merits of road pricing.

Road pricing can be implemented in various ways: on individual links (traffic lanes or roads), on networks of links, within areas (the city center), and in a comprehensive manner through distance-based or time-based charges and/or satellite technology. The choice is driven by technological, practical, legal, institutional, and acceptability constraints, which may evolve exogenously or endogenously over time. Officials should select an implementation path: a sequence of steps that satisfies the constraints and leads to a final system that meets specified goals.

This paper does not identify an optimal implementation path for any city, let alone for Canada. Its focus is limited to determining how road pricing might be introduced in the next few years using established technologies.[28] The candidate schemes selected are a cordon toll for Montreal and networks of links for Vancouver and Toronto. These schemes were chosen largely on the basis of the cities' respective topographies, road construction plans, and the tolled facilities that are or soon will be in place. Only the cordon toll for Montreal is analyzed in any detail, because it is the most well-defined and appears to have the potential to deliver significant net economic benefits.

28. In the longer term, global navigation satellite systems (GNSS) technology is a likely prospect. It is capable of charging for parking, emissions, and insurance as well as for congestion. Moreover, it is scalable and hence could be used for intercity transport and to supplement or replace fuel taxes as a source of transportation funding. If GNSS technology were implemented nationally, environmental benefits and revenue generation would contribute a larger proportion of the benefits than they would with implementation on a city scale since congestion is concentrated in large cities. GNSS technology could be an appropriate choice for Canada, inasmuch as it is a large country with long intercity driving distances, high per-capita transportation infrastructure costs, above-average susceptibility to global warming because of its northern latitude and fragile Arctic ecosystems, and less onerous traffic congestion than many other countries. GNSS for road pricing has been developed by Skymeter Corp. of Toronto. The company's system is interoperable with the E-ZPass system, can be upgraded to a distance-based system, and has been tested on Toronto roads (Grush 2007; www.skymetercorp.com).

Figure 1. Map of Montréal[a]



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a. Major bridges and tunnels marked with red circles: 1 (Honoré Mercier); 2 (Champlain) ; 3 (Victoria); 4 (Concorde); 5 (Jacques-Cartier); 6 (Louis-Hippolyte-LaFontaine Bridge Tunnel); 7 (Pierre Le Gardeur); 8 (Charles-De-Gaulle); 9 (bridge as yet unnamed); 10 (Pie-IX); 11 (Papineau-Leblanc); 12 (Ahuntsic); 13 (Mederia Martin); 14 (LaChapelle [two parallel bridges]); 15 (Louis Bisson); 16 (Île Bizard); 17 (Île aux Tourtes); 18 (Galipeault)

A Cordon Toll for Montréal

The city of Montréal is located on Île de Montréal, an island of 495 square kilometers that is bounded by the St. Lawrence River to the south and the Rivière des Prairies to the north. The island is connected to the mainland and surrounding islands by seventeen bridges and one bridge-tunnel, numbered counterclockwise on the map in figure 1.

The only east-west corridor that traverses the island, the Métropolitaine expressway (Highway 40), is heavily congested and traffic spills over onto other roads. Congestion is exacerbated by gaps in the road infrastructure, particularly in the northeastern part of the island, where there also is no subway service. To help fill the gap, a bridge (number 9 in figure 1) is being built to complete the A25 expressway between Île de Montréal and Laval to the north.[29] The Macquarié Group is financing and building the bridge and will operate it

29. Government of Quebec (2007).

as a toll concession for thirty-five years. The bridge is scheduled to open in 2011; a peak period toll of C$2.40 is proposed.

The city's master plan sets out several priorities for transportation, including facilitating freight movement to maintain the city's competitive position as a freight hub while limiting the environmental impact of road freight transport, upgrading selected highways and building new ones, and giving public transit precedence over the automobile for passenger transportation.[30]

The city's 2007 transportation plan builds on the master plan by proposing twenty-one major initiatives over the next decade, including a bus rapid transit network and an extension of the trucking network.[31] The capital costs and future operating expenditures will be shared with higher-level governments, but the city anticipates an increase in annual expenditures of about C$240 million. The transportation plan indicates that public transit fares should not be increased to help pay for the new commitments and that new sources of funding should be secured instead. It states that "transportation should be regarded as a whole and the sources of overall financing should make it possible to meet the needs for all modes of transportation." It also notes that "tolls on the bridges encircling the island of Montreal could generate net revenues estimated at C$300 million per year on the basis of annual average daily traffic volume."[32] Thus, the city comes out in favor of a cordon toll to finance roads and public transit.

Arguments for a Cordon Toll

Cordon tolls have several generic merits. They have greater potential impact on travel than do either link-based or limited network-based schemes because they encompass a greater area and intercept more trips. Consequently, they offer greater potential for congestion reduction, environmental benefits, and revenue generation. They can be combined with an array of public transit investments and other policy initiatives to improve public acceptability. Area-based schemes also are more acceptable than are smaller-scale schemes insofar as the effects are more readily visible, as was the case in the Stockholm Trial.[33]

A cordon toll is also well-suited to Île de Montréal. Congestion extends over the entire road network, so that an area-based scheme is required to target it effectively. All vehicular traffic to and from the island is carried by the seventeen bridges and one bridge-tunnel. Eighteen potential tolling points are thus

30. City of Montréal (undated).
31. City of Montréal (2007).
32. City of Montréal (2007, pp. 138–39).
33. Hultkrantz and others (forthcoming).

provided, which would suffice to form the cordon. The topography of Montréal makes it difficult for traffic to circumvent the island, so that avoiding the toll by taking alternative routes should not be a major problem. Some Montréal bridges were tolled in the past; the last toll was removed in 1990. Construction of the A25 toll bridge creates a new precedent, and the bridge would form part of the cordon. The large public transit investments that are planned will foster acceptability by offering an improved alternative to driving. A 2007 poll commissioned by the Montreal Economic Institute revealed qualified support among residents for user charges and tolls as a means of paying for roads.[34] The current mayor of Montréal, Gérald Tremblay, supports tolling—no small consideration, given the widely perceived need for prominent champions of road pricing.

Most of the merits of a cordon toll identified above also apply to area charges, through which a fee is levied for entering, leaving, or driving inside the charging zone. The choice between a cordon toll and an area charge has not been systematically examined in the literature. Practical experience is limited, since the London congestion charge is the only operating area-charge scheme and there are no cordon or area-charge schemes in North America. London's scheme has worked reasonably well to reduce congestion, but at least half the revenues are consumed by the capital and labor costs of tracking the movement of vehicles. Area schemes also raise privacy concerns if photos are used for enforcement.

Mayor Bloomberg's initial plan for road pricing in New York City included a toll for entering or leaving the charging zone and an alternative lower charge for driving wholly within it. The scheme was criticized as both complex and costly due to the large number of gantry points required, and the Traffic Congestion Mitigation Commission opted for an inbound cordon toll instead.[35]

A detailed analysis would be required to assess the relative merits of a cordon and an area charge for Montréal. But a priori, a cordon appears to be a better choice as far as simplicity and cost go. The design of a cordon scheme is defined first by the number and location of cordons and by any supplemen-

34. Léger Marketing (2007). Twenty-four percent of respondents believed that road users alone should pay for roads, and 35 percent believed that users rather than taxpayers should bear the majority of the burden. When asked to choose between four types of user charges—tolls on main provincial highways, gasoline taxes, registration and license fees, and recurrent fees based on mileage—52 percent favored the tolls. Among residents of Île de Montréal, the corresponding proportion was 50 percent.

35. Such a scheme has the advantage of charging for both types of trips at separate rates, although—like a single toll cordon—it is crude since each charge is independent of distance traveled and route taken. The cordon toll proposal was rejected by the New York state legislature in April 2008.

tary measures, such as radial screenlines to control orbital movements. All existing cordon schemes have single cordons, and this is a logical choice for Montréal too since the bridges accessing Île de Montréal form a natural cordon. The topography of the region is not conducive to locating a second cordon farther out, and the terrain of the island is probably too uneven to warrant an inner cordon although one or more screenlines could be added.[36]

A second design characteristic is the time structure of the toll. Dynamic pricing is not practical for an area-based scheme because, unlike with HOT lanes, drivers do not have a ready toll-free option if they arrive at a bridge when the toll is higher than they expected. However, variable pricing (time dependent, according to a schedule) is desirable to flatten congestion peaks. All-or-nothing tolls can induce drivers to race to beat a toll increase or to idle while waiting for a decrease.[37] Tolls with large steps may do likewise, as was the case in Singapore until 2003, when five-minute graduated steps were added for certain time periods. A further advantage is that optimal first-best or second-best variable toll schedules are generally lower on average than optimal flat tolls.[38] Variable tolling therefore is more favorable to drivers, and because it induces a smaller reduction in auto trips, there is less need for additional public transportation services.

Since the optimal toll schedule typically varies across access points of a cordon, different schedules should be considered for the Montréal bridges, although they could cause confusion for drivers. And since the A25 expressway would form part of the cordon, its toll should be variable too (the precise structure has yet to be decided). Another consideration is that the optimal time structure for congestion pricing generally is not identical to the optimal structure for revenue generation. If both goals are pursued, determining the appropriate structure becomes more complicated.[39]

A third design consideration is whether to leave some bridges toll free to enhance acceptability. The London, Stockholm, and proposed New York City schemes all feature toll-free links. Each link accessing Île de Montréal has at least one alternative that could be left toll free. The minimum number of links that would be left untolled to provide a toll-free alternative for every tolled link

36. The island suburb of Laval to the north could be included in the charged area by tolling the bridges connecting Laval to the north shore. That would result in a cordon with a rough figure-eight shape.

37. As explained in Leape (2006), in central London travel speeds are relatively constant throughout the day and that was a factor in choosing a single charge throughout the tolling period rather than higher rates during the morning and afternoon peaks.

38. Arnott, De Palma and Lindsey (1993); Braid (1996).

39. Gómez-Ibáñez (1992).

depends on what is considered an acceptable alternative in terms of added travel distance and congestion delay.[40] Tolling only some links would exacerbate congestion on adjacent links because of traffic diversion.[41] However, because the optimal average level of the toll would be lower, the more effective the toll is in suppressing congestion, the smaller the amount of traffic diverted.

Cross-price elasticities of demand between links cannot be estimated with any accuracy without doing road network simulations. Empirical studies find that elasticities depend on many factors: trip purpose, trip frequency, length of the journey, length of the tolled link, average speed, and percentage of heavy trucks on toll-free alternatives.[42] Estimated elasticities are typically lower during peak periods, and most are small.[43]

A fourth design question is whether to charge for inbound crossings only or for outbound crossings too. For the Norwegian toll rings and Singapore's restricted zones, tolls are levied only on inbound vehicles, but in Stockholm the toll applies in both directions. If most drivers travel in and out on the same route, then charging double in only one direction would generate nearly as much revenue while economizing on collection costs. But with electronic toll collection, most costs are fixed and drivers can pay without stopping, so the savings would be small. And since variable tolls influence trip-timing decisions, it is preferable to toll in both directions so as to flatten both morning and evening peaks.

A fifth design issue is discounts and exemptions. Existing road-pricing schemes feature discounts and/or exemptions according to vehicle type (for example, taxis and hybrid vehicles in London), drivers' characteristics (residents in London), and frequency of usage (in Singapore and Stockholm). Naturally, discounts and exemptions are popular with groups that receive them. If a single toll such as a cordon toll is applied over a wide area, second-best efficiency may be achieved by providing discounts or exemptions to individuals such as residents who tend to travel short distances. But in general, discounts and exemptions undermine efficiency. Accounting and enforcement of tolls are easier if vehicles and individuals are treated equally; moreover, opinions can differ regarding who should be favored on grounds of efficiency or fairness.

40. The average distance between adjacent bridges on Île de Montréal is about 4.5 kilometers.

41. For trips across Île de Montréal (for example, between Laval and the south shore), two links would be driven in series. Since these links would be complements for such trips, rather than substitutes, tolling one link would alleviate congestion on both links.

42. Burris (2003); Matas and Raymond (2003).

43. Hirschman and others (1995) presents a median elasticity estimate of -0.1 and a maximum elasticity of -0.5 for New York City bridges and tunnels.

Estimating the Economic Benefits from a Cordon Toll

This section presents a rough estimate of the potential economic benefits from a cordon toll around Île de Montréal. Two approaches are discussed: the first employs a static congestion-pricing model; the second draws on analyses of cordon tolls that were undertaken using a dynamic road network simulator.

STATIC MODEL ASSESSMENT. In the traditional static congestion-pricing model, automobile trips are made from a single origin to a single destination with one person per vehicle.[44] The number of trips, N, is the only endogenous variable. Public transit and other substitutes for driving are distortion free and omitted from the welfare analysis. Trip demand is a decreasing function of the generalized cost or price, p, and the user cost of a trip net of any toll is an increasing function of N. To derive order-of-magnitude estimates, a linear inverse demand function, $p(N) = a - bN$, and a linear user cost function, $C(N) = c + dN$, are used.[45] Parameters, $\{a, b, c, d\}$, are all positive and calibrated for inbound morning peak trips to Île de Montréal by using four characteristics of the equilibrium without tolls (that is, the status quo): the number of car trips (N_e), the generalized cost of a trip (p_e), the price elasticity of demand (*eta*), and the proportional increase in travel time due to congestion (*%tt*). Base-case values of these and other parameters discussed below are derived in the appendix and listed in the footnote to table 3.

Parameter c in the user cost function denotes free-flow cost. It is the sum of travel time cost, vehicle operating cost, parking cost, and schedule delay cost (that is, the cost of arriving earlier or later than desired); the first two costs are assumed to be proportional to distance traveled, *dist*. Parameter d captures congestion and any accident costs that are external to an individual driver but borne by drivers collectively. To account for local pollution, climate change, and other costs that are not borne by drivers individually or collectively, it is assumed that vehicles generate an external cost of e per kilometer.

The static model disregards the fact that suitably designed time-varying tolls can reduce the aggregate resource cost of a given number of trips by inducing changes in trip departure times. As in Arnott and others (1993), this effect can be captured in the static model by specifying the user cost function with tolls as $c + \Gamma dN$, where parameter Γ depends on the time structure of the toll. As Arnott and others demonstrated, for the bottleneck queuing model with identical users and linear schedule delay costs, $\Gamma = 1$ for a flat toll, $\Gamma \approx 0.75$ for an optimal one-step toll, and $\Gamma = 0.5$ for a fine (continuously time-varying) toll that eliminates queuing.

44. Walters (1961).

45. A similar approach using linear functions is taken in Hyman and Mayhew (2008).

Table 3. Impacts of Cordon Toll for Montréal[a]

Canadian dollars (millions)

	Variant	*Toll (C$)*	*Change in trips (percent)*	*Revenue*[b]	*Welfare gain*[b]	*Gain/revenue*
	Base case	2.17	-9.4	180.7	10.2	0.056
1	$e = 0$	1.93	-8.3	162.5	8.1	0.050
2	*dist* = 8 km	1.81	-9.3	150.8	8.5	0.056
3	*dist* = 12 km	2.53	-9.4	210.7	11.9	0.057
4	$\eta = -0.33$	2.23	-6.6	191.2	7.2	0.038
5	$\eta = -0.75$	2.09	-13.0	167.5	14.1	0.084
6	*%tt* = 0.1667	1.65	-7.3	141.0	6.0	0.042
7	*%tt* = 0.375	2.79	-11.7	227.0	16.8	0.074
8	$\Gamma = 0.75$	Mean 1.75	-5.4	152.6	51.6	0.338
9	$\Gamma = 0.50$	Mean 1.30	-1.1	118.4	96.8	0.818
10	*MCPF* = 1.1	3.62	-15.7	281.1	33.7	0.120
11	*MCPF* = 1.2	4.69	-20.3	343.9	65.2	0.190
12	*MCPF* = 1.5	6.66	-28.8	436.3	184.5	0.423
13	*MCPF* = 2.0	8.25	-35.7	488.1	418.1	0.857

Source: Author's calculations.

a. Base-case parameters: $\eta = -0.5$, *%tt* = 0.25, e = C$0.0263/km, dist = 10 km, *MCPF* = 1, $\Gamma = 1$.

b. Annual revenues and gains in millions of Canadian dollars based on two peaks a day, 250 days a year.

A final objective of the model is to account for the disposition of toll revenues, which—depending on how revenues are spent and the size of preexisting distortions in the transportation sector and elsewhere—can yield efficiency gains or losses greater in magnitude than the Pigouvian efficiency gains from congestion relief.[46] In Montréal, the capital and operating costs of the major road network and the local road network, capital costs of the public transit system, and operating costs of local and regional public transit are all financed by different levels of government and from different mixes of fuel taxes, property taxes, registration fees, fare revenues, parking fees and fines, and subsidies. As noted earlier, estimates of the marginal cost of public funds in Canada vary widely by the type of tax. A range of values for MCPF clearly warrants consideration. To be conservative, the base-case value is set to unity.

Although the model is calibrated only for inbound morning peak trips, the cordon toll is assumed to operate in both directions throughout the day. For accounting purposes it is assumed that the evening and morning peaks are symmetric and that the toll operates for 250 workdays a year, so that the model results can be converted to annual figures by multiplying by 500.[47] Off-peak

46. Parry and Bento (2001); De Palma, Lindsey, and Proost (2007).

47. Evening peaks are typically flatter than morning peaks but more prolonged. In queuing

congestion is growing on some Montréal expressways, and tolling during the off-peak periods would yield additional benefits. The annual estimates are therefore conservative.

For the simulations, it is assumed that the toll is set to maximize welfare as defined by the triple goals of congestion relief (quantified by parameters d and Γ), alleviation of other external costs (quantified by parameter e), and revenue generation (quantified by parameter *MCPF*).[48] Results for alternative parameter assumptions are reported in table 3. For the base-case parameters, the optimal toll is C$2.17. It reduces the number of automobile trips by nearly 10 percent and yields C$180.7 million in annual revenues and a welfare gain (gross of toll infrastructure and operating costs) of C$10.2 million. In variant 1, the external cost of auto trips is set to zero, reducing the toll, toll revenues, and welfare gain only slightly. Thus, as in the findings of Transport Canada's study, the costs of congestion dominate the costs of other external costs of auto travel in the welfare analysis. The welfare gain is roughly proportional to distance traveled (variants 2 and 3), price elasticity of demand (variants 4 and 5), and percentage of congestion delay (variants 6 and 7).

The base case and variants considered thus far yield revenues of roughly C$180 million, an amount that is broadly in line with the city's estimate, quoted earlier, for net revenues of "up to $300 million per year." But the welfare gain is relatively modest, amounting only to from 4 to 8 percent of toll revenues. By comparison, operating costs as a fraction of revenues for existing area-based schemes are 21 percent for Singapore, 10 percent for the Oslo toll ring, 5 percent for the Bergen toll ring, about 50 percent for London, and 22 percent for the Stockholm Trial, which has the same number (eighteen) of entry points.[49] Those figures suggest that a cordon toll would not yield a positive net economic benefit unless operating costs could be reduced below the levels achieved with contemporary schemes. However, the picture changes markedly with the remaining variants in table 3.

For variant 8, parameter Γ is reduced from the base-case value of 1 to 0.75 to emulate the effects of an optimal one-step (peak/off-peak) toll. The average toll paid drops from C$2.17 to C$1.75. Because the toll reduces congestion delay by spreading departures, user cost drops as well, and the number of trips declines by only 5.4 percent. The welfare gain increases fivefold in magnitude and sixfold in proportion to revenues. For variant 9, parameter Γ is further reduced to 0.50 to emulate the effects of a toll that eliminates queuing. The

models the two peaks behave differently and the benefits from congestion pricing differ as well (De Palma and Lindsey 2002).

48. The toll formula is given in the appendix.

49. These statistics are drawn from various sources cited in table A1 in Lindsey (2007).

welfare gain nearly doubles again and rises to more than 80 percent of revenues.

The final set of variants considers alternative values for *MCPF*. As *MCPF* rises, the toll increases sharply, as does the percent reduction in trips, toll revenues, and welfare gain. As the toll approaches the revenue-maximizing level (C$11.56), the rate of increase in revenues slows but the welfare gain continues to increase rapidly.

Three results from the static model stand out. First, the benefits from congestion relief dominate the benefits from alleviating other external traffic costs. Second, the benefits from congestion relief are much higher for a time-varying toll than for a flat toll. And third, for large values of *MCPF*, the benefits from revenue generation dominate the benefits from congestion relief.[50]

Naturally, those conclusions are only indicative given the simplicity of the model. One limitation is that the model is not spatial and disregards the spillover effects of the cordon toll on the rest of the untolled road network. Given the topography of Montréal, most of the untolled links both on and off Île de Montréal are in series rather than in parallel with the cordon links. Reducing traffic on the cordon links therefore should reduce congestion elsewhere as well. However, that benefit could be diluted by induced demand. Induced demand within Île de Montréal is a potential concern because about 465,000 morning peak automobile trips began and ended on the island in 2003—some 2.5 times the 184,000 trips to the island from the rest of the Montréal region.[51]

Two other limitations of the model are its crude treatment of departure time decisions and the assumption that travelers are identical except for their reservation price to drive. These limitations were avoided in two recent studies of cordon tolls that are briefly reviewed below.

DYNAMIC NETWORK MODEL RESULTS. As part of a European Union project on implementation paths for road pricing, De Palma and Lindsey (2006) assessed several road-pricing schemes for the Paris region, an area of more than 12,000 square kilometers with a road network of nearly 18,000 links. Simulations were performed for morning (4:00 a.m. to 12:00 p.m.) trips using the dynamic network simulator METROPOLIS, a tool that treats the individual traveler's choice of mode, departure time, and route endogenously. Congestion

50. At sufficiently high toll levels, the Pigouvian benefits are negative because the number of trips is reduced well below the Pigouvian optimum.

51. City of Montréal (2007, figure 2). Induced demand could be curbed by restricting parking spaces and raising parking fees on the island. The city's master plan goes in that direction by proposing ceilings on the number of parking spaces at sites close to Metro (the subway system) and to commuter train stations and a requirement for employers to cash out free parking by granting employees an equivalent sum for using public transportation.

delay was assumed to take the form of queuing at junctions.[52] The generalized cost of public transport was assumed to be exogenous and independent of time of day, so neither scale economies nor congestion on public transport was modeled. One of the schemes studied was a cordon toll levied on inbound trips to the city center, a relatively small area of about 12 square kilometers. An (approximately) optimal two-step toll was identified with a peak toll of C$10.30 from 7:00 to 10:00 a.m. and an off-peak toll of C$6.86 from 4:00 to 7:00 a.m. and 10:00 a.m. to 12:00 p.m.

The main results of interest are reported in row 2 of table 4, with the results of the static model for Montréal reproduced in row 1 to facilitate comparison. Although the Paris tolls are much higher than the Montréal tolls, the percent reduction in trips is much smaller because the Paris cordon toll is paid on less than 3 percent of all trips in the study area. Annual revenues are nearly triple the revenues from the two-step Montreal toll and the welfare gain is seven times as large. Most striking is that the welfare gain is nearly as big as the revenues. The large gain is not attributable either to reductions in external costs—which account for less than 10 percent of the total—nor to a premium on toll revenues, which are excluded from the results reported here. Rather, the benefits derive from reductions in user costs—that is, travel time, schedule delay, and accident costs.

Another set of simulations using METROPOLIS was presented in De Palma, Kilani, and Lindsey (2005a) for a smaller, artificial, road network in order to examine more precisely the differences between tolling schemes in efficiency and revenue generation. The road network considered is circular and symmetric, with eight arterial routes 45 degrees apart and four ring roads spaced at 4-kilometer intervals. Trip origins and destinations are concentrated toward the city center. The cordon was defined by the second ring road, enclosing an area of about 200 square kilometers. Two toll structures were evaluated: a flat toll and a toll with four steps, at 30- minute intervals. As shown in row 3a of table 4, toll levels and percent reductions in trips are intermediate between those obtained for Montréal and Paris. As with Montréal, the step toll yields lower revenues than the flat toll but a considerably higher welfare gain. No benefits from either external cost reductions or revenue generation were considered in the study, so all benefits derive from reductions in user costs.

In addition to the cordon toll, an area charge within the same boundary was assessed. The charge was assumed to be paid for all trips, whether they crossed

52. Queuing is the dominant source of delay in many urban areas (Santos 2004), and reduced queuing at junctions accounts for most of the travel time savings from the London congestion charge (Leape 2006).

Table 4. Comparison of Static and Dynamic Network Simulation Model Results
Canadian dollars (millions)

	Model	*Toll type*	*Toll (C$)*	*Change in trips (percent)*	*Revenue*[d]	*Welfare gain*[d]	*Gain/revenue*
1	Montreal cordon[a]	Flat	2.17	-9.4	180.7	10.2	0.056
	(base case)	2-step	Mean 1.75	-5.4	152.6	51.6	0.338
2	Paris city center cordon[b,e]	2-step	6.86, 10.30	-1.8	413.9	361.0	0.872
3a	Circular city	Flat	4.97	-6.2	44.3	12.5	0.281
	cordon[c]	4-step	0.00 to 5.78	-2.3	32.0	23.7	0.742
3b	Circular city	Flat	4.30	-10.6	89.1	19.0	0.213
	area charge[c]	4-step	0.00 to 4.41	-5.7	60.4	33.1	0.547

a. Author's calculations.
b. De Palma and Lindsey (2006).
c. De Palma, Kilani, and Lindsey (2005a).
d. Annual revenues and gains in millions of Canadian dollars based on two peaks a day, 250 days a year.
e. Monetary values translated using €1.00 = C$1.50 and taking mean of high and low environmental cost valuations.

into the charge zone or started within it. The optimal flat and step tolls are a bit lower than for the cordon toll (see row 3b) since trips that start in the center tend to be shorter and to use relatively less congested outbound links. But because the area charge is paid by more drivers than is the cordon toll, trip reductions and revenues are considerably larger. The welfare gain also is somewhat higher, but it is smaller as a proportion of revenues. Furthermore, a larger fraction of travelers are worse off with the area charge, and the average loss of consumer's surplus is greater.[53] Toll collection costs were not considered; doing so would have improved the performance of the toll cordon relative to the area charge.

While the cordon tolls studied for Paris and the circular city network differ greatly in scale, number of travelers, and other features, they are similar in generating large user benefits in proportion to revenues. That suggests not only that a cordon toll for Montréal would yield net benefits after deducting capital and operating costs, but also that it would generate significant net revenues that could be used to fund road or public transit investments that would improve the acceptability of tolling. Alternatively, the revenues could be used to reduce other distortionary taxes which, as analysis with the static model suggests, could greatly increase the net economic benefits.

53. Consumer's surplus is the difference between what a consumer is willing to pay for a good or service and the amount actually paid.

The METROPOLIS simulations summarized above omit several factors that if incorporated probably would boost the estimated benefits further:

—The simulator includes mode, departure time, and route choice decisions, but it ignores destination choice, vehicle occupancy, parking, and other short-run choices as well as longer-run location and land use decisions, all of which could be influenced by tolling in socially beneficial ways.

—The specification of public transit is crude and ignores the potential benefits from economies of traffic density that would accrue from greater use of mass transit.

—The simulations account for recurrent congestion but not nonrecurrent congestion, which accounts for a large proportion of total delays in larger cities.

—Truck traffic is ignored. Trucks impose greater congestion delays than do light vehicles, and they also suffer more from congestion because of their higher average value of travel time. They also create more pollution, safety hazards, and road damage.

Perhaps the most compelling evidence in favor of cordon tolls comes from studies of the Stockholm Trial in Hultkrantz and others (forthcoming), Eliasson (2008), and Lundqvist (2008). Eliasson (2008) estimates the annual benefits from reduced travel time to be SEK496 million or about C$79 million. More reliable travel times add another SEK78 million (16 percent) to the benefits. Those benefits amount to about 70 percent of toll revenues, a figure broadly in line with the METROPOLIS results reported in table 4. Much of the benefit is realized by travelers who did not cross the cordon but still gained from congestion relief.

As noted earlier, the Canadian public is gradually becoming more favorably disposed toward road pricing. Probably the greatest remaining obstacle to introducing a cordon toll in Montréal is the lack of a single institution with the mandate to do it. Five institutions are involved in transportation in Montréal. The provincial transportation ministry (Ministère des Transports du Québec) has prime responsibility for roads. Agence Métropolitaine de Transport manages and funds the metropolitan commuter train network, and it reports to the Communauté Métropolitaine de Montréal, an organization of elected officials from the five regions of Montréal. Société de Transport de Montréal organizes public transportation within Montréal's boundaries. The federal government owns the Honoré Mercier bridge and controls the Champlain and Jacques Cartier bridges, and it would have to approve new tolls on them. Coordination and agreement among the different levels of government therefore would be necessary to introduce a cordon toll and to approve any accompanying public transit improvements or other measures of a politically viable road-pricing package.

Candidate Scheme for Vancouver

Vancouver is part of the Greater Vancouver Regional District (GVRD) and the larger Lower Mainland area. Downtown Vancouver has one of the highest population densities in North America, and it is the only major city in North America without a freeway system in the center.[54] Overall, travel conditions within downtown and between downtown and other regions have been improving. Between 1974 and 1996, morning peak trips by auto decreased by 35 percent while trips on foot and bicycle more than doubled.[55]

Traffic outside downtown poses a more serious challenge. The estimated cost of congestion per capita for the whole Vancouver area is the second highest in Canada (table 2) and public transit accounts for a much smaller share of work trips than in Montréal or Toronto. Commuting patterns are highly dispersed. More than 60 percent of commuters cross municipal boundaries, and most of the growth in commuting flows is occurring between suburbs and from the city of Vancouver to the suburbs.[56] Public transit serves only 4 percent of suburb-to-suburb travel.[57] Container movements through the Port of Vancouver are growing very rapidly, fueled by a boom in trade with China, and container traffic is expected to triple by 2020. Truck traffic is growing commensurably, contributing to congestion delays that impede passenger transportation as well as disrupt freight supply chains.[58]

As in Montréal, control over transportation in the GVRD is divided. The British Columbia Ministry of Transport is responsible for planning and coordination of highways and other modes of transportation throughout the province. Municipalities are responsible for day-to-day operations on local roads. TransLink (the Greater Vancouver Transportation Authority) has authority for roads and public transportation in the GVRD as well as responsibility for long-range transportation and land use planning. It receives dedicated funding from transit fares, fuel taxes, parking taxes, and property taxes. It may assess charges on motor vehicles that are used primarily within the region but does not currently do so. It also may levy tolls to recover the cost of improvements to major roads.

The province currently is investing in regional road and transit improvements, including eight new road projects, and it announced a massive C$14 billion

54. City of Vancouver (2005).
55. City of Vancouver (2001).
56. Government of British Columbia (2006).
57. Greater Vancouver Transportation Authority (2004a, pp. 1–3).
58. The British Columbia Trucking Association has estimated the cost of congestion to freight movement in the GVRD as C$500 million annually (Government of British Columbia, 2006, p. 1).

transit investment plan in January 2008. It also is building a new bridge across the Fraser River, the Golden Ears Bridge, under a 35-year contract to finance, design, build, maintain, and rehabilitate the bridge. Tolls will be collected on behalf of TransLink and used to pay the private partner. Although electronic tolling technology will be used, the planned tolls are flat. Tolls for cars are C$2.85 for payment using transponders, C$3.45 for prepaid video toll, and C$4.00 for postpaid video toll.[59]

In response to congestion problems, in early 2006 the province embarked on the ambitious Gateway program, administered by the Ministry of Transportation in consultation with TransLink and local municipalities.[60] The Gateway program includes a further set of major transportation infrastructure projects. The centerpiece is the Port Mann–Highway 1 project to twin the Port Mann Bridge crossing the Fraser River, upgrade Highway 1 (the Trans-Canada Highway), extend high-occupancy vehicle (HOV) lanes on Highway 1, and expand public transit across the Port Mann Bridge. The bridge is to be tolled; the provisional toll is a flat rate of C$2.50.

The Gateway program treads a fine line between the goals of accommodating freight transport and improving the competitiveness of Vancouver vis-à-vis other gateways and of reducing congestion and emissions. Attitudes toward the program vary widely among public agencies and the public. The GVRD opposes the program mainly because it will increase general purpose traffic capacity instead of targeting capacity related to activities critical to the regional economy.[61]

Although the province approved tolling of the Golden Ears and Port Mann bridges, tolling is constrained by British Columbia's guidelines for setting tolls.[62] The most significant barriers are guideline 2.1, which states that "only major projects that result in significant increases in capacity will be subject to tolling," and guideline 2.3, which states that "tolls will be implemented only if a reasonable untolled alternative is available."

Despite the guidelines, tolling is gaining advocates. The GVRD supports a regionwide road-pricing strategy.[63] TransLink is supportive of tolls, which it will collect as owner of the Golden Ears Bridge. There is mixed support for the Port Mann–Highway 1 project among municipalities but greater support

59. "Golden Ears Bridge: Improving Travel Times and Connecting Communities" (www.translink.bc.ca/goldenearsbridge/Tolling/Toll_Rates.asp [May 2008]).

60. The federal government's Asia-Pacific Gateway and Corridor Initiative, launched in October 2006, is providing additional funds (Transport Canada 2006d).

61. Greater Vancouver Regional District (2007b).

62. British Columbia Ministry of Transport and Highways (2003, paragraph 2).

63. Greater Vancouver Regional District (2006, p. 1).

for tolling the bridge as part of a comprehensive regional approach to road pricing. Comprehensive tolling also is backed by the Consulting Engineers of British Columbia on the grounds that tolling just one or two bridges would divert too much traffic to other routes.[64] According to the engineers, bridges into downtown Vancouver could also be tolled, but at a lower rate since they are less congested.[65] There also is majority backing in some municipalities for tolls if they are levied throughout the region to maintain geographical equity.[66]

In October 2007, TransLink issued a document outlining transportation plans for the year 2040 and invited comments on it; eight institutions submitted their perspectives.[67] Two made no reference to road pricing, and one made a single, neutral, reference to road pricing and pay-as-you-drive insurance. The other five institutions supported tolling in some form, and all but one backed preferential treatment for freight transport over commuter and other personal transportation. The Consulting Engineers of British Columbia supported time-of-day charges and recommended "strict accountability for the disposition of revenues."[68] The British Columbia Chamber of Commerce criticized the provincial government's policy of permitting tolls only on new facilities with a viable and toll-free alternative and stated that the policy "must be reviewed."[69] Although they do not represent a random sample of opinion, the submissions reveal considerable support for road pricing, particularly for personal travel.

The case for road pricing in the GVRD is similar in several respects to the case in Montréal. The region has serious and growing congestion; it has major road and public transit investment plans; and as a gateway city, Vancouver has a strong incentive to facilitate freight transport. But unlike Montréal, the GVRD does not have a natural cordon such as the one formed around Île de Montréal. The downtown is relatively small, and travel conditions there are better than

64. Bill Boei, "Tolls Needed on all Vancouver Bridges, Tunnels, Engineers Say," *CanWest News Service*, November 14, 2006.

65. According to Glenn Martin, executive director, the organization has not conducted a survey on how congestion pricing might be implemented in the Vancouver area (personal e-mail message to author on August 16, 2007).

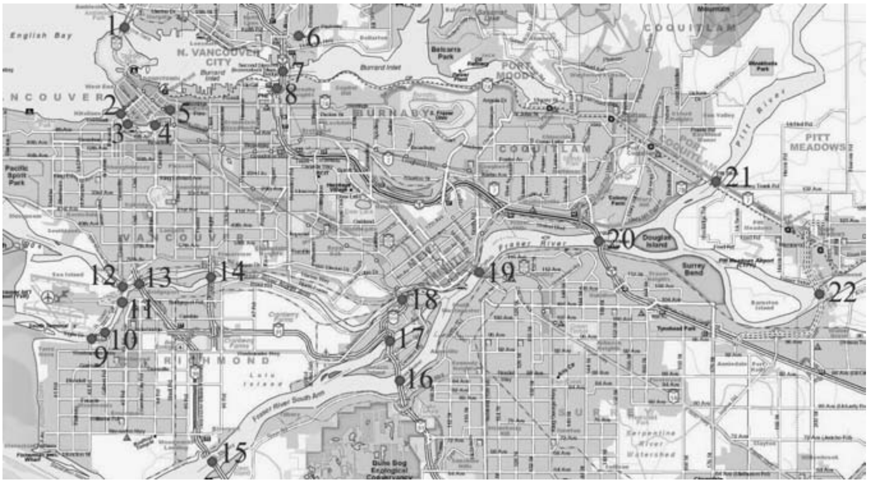
66. Jeff Nagel, "GVRD Won't Give Up On Tolling," *Black Press*, October 11, 2006 (www.surreyleader.com/portals-code/list.cgi?paper=73&cat=23&id=746817&more [October 2006]).

67. Greater Vancouver Transportation Authority (2007). The eight responders were the British Columbia Chamber of Commerce; Better Environmentally Sound Transportation (BEST), an environmental organization; the Consulting Engineers of British Columbia; the Fraser Basin Council, a nongovernmental, not-for-profit, nonpartisan organization; the Greater Vancouver Gateway Council; Smart Growth British Columbia; SPARC British Columbia, a public education and advocacy organization; and the Vancouver Board of Trade. The submissions are posted at www.translink.bc.ca/files/pdf/2040/perspectives.

68. Page 5 of submission.

69. Page 7 of submission.

Figure 2. Major Bridges and Tunnels in Greater Vancouver



a. Major bridges and tunnels marked with red circles: 1 (Lions' Gate); 2 (Burrard St.); 3 (Granville St.); 4 (Cambie St.); 5 (Georgia Viaduct); 6 (Dollarton); 7 (Second Narrows); 8 (Cassiar Connector Tunnel); 9 (No. 2 Road); 10 (Dinsmore); 11 (Sea Island); 12 (Arthur Laing); 13 (Oak St.); 14 (Knight St.); 15 (George Massey Tunnel); 16 (Alex Fraser); 17 (Derwent Way); 18 (Queensborough); 19 (Pattullo); 20 (Port Mann); 21 (Pitt River); 22 (Golden Ears); Westham Island bridge is off southwest corner of map.

elsewhere in the GVRD. The best prospect appears to be tolling major bridges and tunnels, as suggested by the Consulting Engineers of British Columbia.

Including the new Golden Ears and Port Mann bridges, there are twenty-two major bridges and two tunnels in the GVRD (figure 2).[70] Tolling all of them would intercept a large fraction of total traffic, and since no toll-free alternative land routes exist, there would be no significant problems with traffic diversion. Tolling all bridges also would be geographically equitable. And there would be potential for significant emissions reduction and revenue generation.

Arguments related to the structure of the tolls are similar to those for the Montréal toll cordon. To target congestion, the tolls should be variable, including tolls on the Golden Ears and Port Mann Bridges for which flat tolls are currently planned. The case for adopting different time schedules is stronger than for Montréal because the bridges serve widely varying origins and destinations, and presumably they experience peaking at different times. Arguments against discounts and exemptions are also stronger since there is no natural division of the population into "insiders" and "outsiders."

70. The Moray Bridge and Sea Island Bridge are adjacent one-way bridges that are counted as one in the total (number 11 in figure 2).

If tolls cannot be introduced on all bridges and tunnels at once, the question arises of how to phase them in. Since travel conditions in the downtown compare favorably with those elsewhere in the GVRD, tolling the Burrard Street, Granville Street, and Cambie Street bridges (numbers 2, 3, and 4 in figure 2) probably would not be the highest priority. Theory suggests that tolling substitute links is a higher priority than tolling links that are complements.[71] Several sets of substitutes and sets of complements are identifiable in figure 2.

The Port Mann Bridge (20) and Golden Ears Bridge (22), which are scheduled to be tolled, are nearest-neighbor substitutes for crossing the Fraser River, although the bridges are 12 kilometers apart. The Pattullo Bridge (19) is another substitute for the Port Mann Bridge, and fears have been expressed that it will be swamped by diverting traffic when the Port Mann Bridge is tolled. In contrast, the Pitt River Bridge (21) is in series with the Golden Ears Bridge, and tolling the Golden Ears Bridge would reduce congestion on the Pitt River Bridge as well. To estimate the benefits of tolling any subsets of links, a travel demand model encompassing the GVRD would be required.

Candidate Scheme for Toronto

Toronto is part of a densely populated region of more than 8 million people at the west end of Lake Ontario. Freeways and public transit are heavily congested and together carry nearly half a million commuters a day across municipal boundaries in the Greater Toronto Area (GTA) and Hamilton. Average commuting times are the highest in Canada. In 2006, the provincial government launched a five-year highway construction program, and it is planning extensions of existing 400-series highways as well as new highways and corridors.[72] It has started to build a 450-kilometer network of HOV lanes and it is rehabilitating and improving Highway 401. In 2006, the province also announced a C$17.5 billion transit investment plan, "MoveOntario 2020," for the GTA and Hamilton; the cost is to be shared by the provincial and federal governments.[73]

Highway 407 is the only tolled road in the GTA. There are no plans to introduce more tolls although the possibility has been widely discussed. As in Montréal and Vancouver, administrative power over road pricing and other measures to manage transportation demand is divided. The Ontario Ministry of Transport can make decisions on provincial highways unilaterally. Control

71. Verhoef (2002).

72. Government of Ontario (2006).

73. "McGuinty Government Action Plan for Rapid Transit Will Move the Economy Forward," June 15, 2007 (www.premier.gov.on.ca/news/Product.asp?ProductID=1383 [May 2008].

at the regional and municipal level changed in June 2006 with the creation of the Greater Toronto Transportation Authority, now called Metrolinx. Metrolinx is legally empowered to levy tolls on municipal roads. But a special regulation is required, and because of junctions between municipal and provincial road networks and interdependent traffic flows, the provincial government would have to be involved in any tolling initiative.

An area-based road-pricing scheme using conventional technology in the GTA area seems unlikely in the near term. Unlike Montréal, the GTA does not have a natural boundary for a cordon or an area charge. In Toronto, as in Vancouver, congestion is not concentrated in the downtown area,[74] but Toronto, unlike Vancouver, does not have a set of bridges and tunnels that intercepts most long-distance traffic flows. Tolling 400-series provincial highways and regional and municipal roads in the GTA has been proposed, but that would require cooperation between the province and Metrolinx, and it would involve tolling existing toll-free infrastructure.[75]

The best near-term opportunity for road pricing appears to reside with the 450-kilometer network of HOV lanes that is being built on 400-series highways, which could be adapted to a network of HOT lanes. Tolls can be introduced unilaterally by the Ontario government. The Ontario Ministry of Transportation has indicated that "the Province does not intend to toll existing 400 series highways," but the HOV lanes under construction would constitute new capacity and the existing lanes would remain toll free.[76]

The planned HOV network is shown in figure 3. Highways in the area were selected for inclusion in the network according to three main criteria: projected volumes of at least 500 vehicles per peak commuting hour; potential for use by transit vehicles; and opportunity to build HOV lanes in conjunction with other highway projects.[77] Most of the HOV lanes are to be constructed as new highway lanes.

To date HOV lanes have been established on north- and southbound lanes on Highway 403 and 404. They operate as HOV lanes twenty-four hours a day, seven days a week.[78] They are open to buses regardless of occupancy and to other vehicles carrying at least two people (HOV2+), except trucks that are more than 6.5 meters long, which are prohibited for safety reasons. To encour-

74. Hemson Consulting (2007).

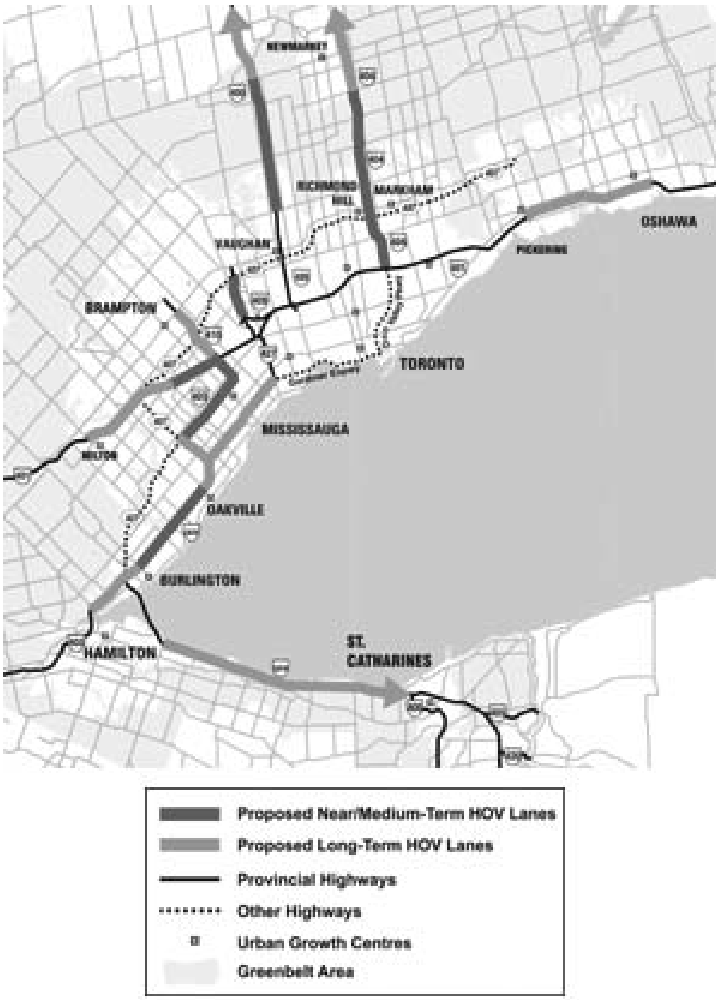
75. Toronto City Summit Alliance (2007); Metrolinx (2008); Kitchen (2008).

76. Grush and Peters (2007, p. 4).

77. Ontario Ministry of Transportation (2007).

78. The ministry explains that the lanes experience high volumes for most of the day and intermittent operation might confuse drivers.

Figure 3. HOV Lanes Planned (Longer Term) for Greater Toronto Area



Source: Ontario Ministry of Transportation (www.mto.gov.on.ca/english/traveller/hov/plan2007.htm [August 28, 2007]).

age use of the lanes, dedicated parking space for carpoolers and transit users will be expanded as the network develops.

The limitations of HOV lanes and the merits of HOT lanes have been evaluated extensively in the literature. HOV lanes are effective only when initial congestion is substantial and when the initial modal share of carpools is sizable. Lane capacity indivisibilities make it difficult to allocate capacity between vehicle categories in efficient proportions.[79] The main generic advantages of a HOT lane network for the GTA are as follows:

—The lanes are relatively cheap to build or convert.

—HOT lanes offer single-occupancy vehicles (SOVs) the option of paying for a quick and reliable trip and they provide insurance for carpool members in case a member is not available on a given day.

—Giving SOVs a legal option to use the HOV lanes may reduce the violation rate.

—Usage of HOT lanes is only weakly correlated with household income and an appreciable portion of low-income households benefit from them.[80]

—There is evidence that HOT lanes can actually support a higher throughput than general purpose lanes, although the matter is controversial.[81]

—Critics of HOT (and HOV) lanes argue that providing discounts or exemptions on the basis of occupancy is inefficient since occupancy does not materially affect the congestion that a vehicle causes. In fact, Small and others (2006) find that a one-route toll without exemptions is slightly inferior to HOT lanes, both for their base-case simulations and for their "low HOV share." Discounts or exemptions based on vehicle occupancy also may be defensible theoretically on the grounds that ride sharing is inconvenient to participants and Coasian bargaining is not completely effective in internalizing the externality.

According to the Ontario Ministry of Transportation, the existing HOV lanes on highways 403 and 404 have performed well. Carpool participation during peak periods has more than doubled on two of the lanes, [82] and mean travel times in the morning peak are 6 minutes shorter than on the general purpose lanes. Although that differential is below the benchmark of 10 minutes considered for HOV-to-HOT conversion projects in the United States, the differential is likely to increase as traffic grows.[83] And the travel time savings will be cumulative for drivers who use a series of lanes on the network. Excess capacity also currently exists on the HOV lanes. The highest flow is 1,350 vehicles per hour on Highway 404 southbound, which is well below typical HOV lane capacity.[84] If use of the lanes by HOVs eventually increases to the point

79. Dahlgren (1998).

80. Small, Winston, and Yan (2006).

81. Kim (2000); Evans and others (2007).

82. Ontario Ministry of Transportation (2006, 2007).

83. Swisher and Ungemah (2006).

84. Ministry of Transportation, "Two Occupants Proving Better Than One" (www.ogov.newswire.ca/ontario/GPOE/2006/12/13/c6876.html?lmatch=&lang=_e.html [May 2008]).

that few SOVs can be accommodated without degrading performance, the HOV occupancy requirement could be tightened from HOV2+ to HOV3+.

Various design aspects of the HOT lane network would have to be decided. Discussion here is limited to their geographical coverage and time structure. Tolling all lanes on the network can be defended on two grounds. First and foremost, it would allow SOVs to benefit from network-scale economies that arise from the fixed costs of acquiring and installing transponders and paying bills, the fixed time costs of participating in carpools, and the benefits of being able to take more trips (and to travel a greater proportion of the distance on a given trip) quickly and reliably. Second, it is more spatially equitable insofar as all 400-series highways in the region with dedicated lanes are priced in the same way.

Practice varies with respect to the time structure of tolls. Of the six existing HOT lane facilities in the United States, four employ variable pricing. Dynamic pricing is used on the I-15 express lanes in San Diego County and on the I-394 HOT lanes in Minneapolis–St. Paul. Tolls on each facility are adjusted to maintain level of service C or better.[85] The tolls have met with public approval, but so has variable pricing on the SR-91 express lanes in Orange County, California. The I-15 and I-394 lanes are single links. Since the GTA network would include a number of links in series, a decision would have to be made on whether to set tolls separately on every link between access points.[86]

The advantage of dynamic pricing is that it accommodates unanticipated demand and capacity shocks. According to the Ontario Ministry of Transportation, about 60 percent of delays on urban highways is due to collisions and spills or other debris.[87] The proportion of congestion that is nonrecurring is presumably even higher after bad weather, special events, and so on are factored in. Setting tolls responsively to maintain service of a given quality has inherent advantages.[88] Unlike with second-best pricing, only local information is required (that is, regarding traffic flows and delays on the tolled links). The goal is well-defined, visible (and hence verifiable), and readily explained and promoted to the public. And—unlike variable pricing, which operates according to a schedule—it has the advantage that increases in tolls do not have to be approved.

85. The *Highway Capacity Manual* defines a highway's operating conditions in terms of levels of service. Level of service C corresponds to densities of eleven to sixteen passenger cars per kilometer per lane and speeds close to but slightly below free-flow speed (Transportation Research Board 2000).

86. I-15 is being expanded to a 20-mile managed-lane facility with intermediate entrances and exits, and a distance-based dynamic toll will be charged.

87. Ontario Ministry of Transportation (2005).

88. De Palma, Kilani, and Lindsey (2005b).

A HOT lane network in the GTA would operate on a smaller scale than the schemes proposed for Montréal and Vancouver. It would not yield comparable benefits in congestion relief, emissions reduction, or revenue generation, although it is not clear that it would be less cost effective on all those counts, especially if free-flow conditions are maintained by dynamic pricing. The HOT lane network has three principal merits. First, construction can begin relatively quickly and the plan poses low technological risks. Second, most of the capacity will be new and the public more readily accepts tolls when levied on new capacity. Third, unlike with Highway 407, the time savings from using HOT lanes are evident (just as they are to users of HOV lanes) since the general purpose lanes are adjacent. It is easier to build the lanes as HOT from the start than to convert them from HOV. Consequently, early introduction is advantageous from the perspective of both political economy and operations.

Concluding Remarks

Congestion adversely affects the quality of life in major Canadian cities, and it appears to be severe enough in the three largest cities—Toronto, Montréal, and Vancouver—to warrant consideration of road pricing in some form. Moreover, traffic congestion is likely to get worse in the near-term future as automobile use continues to grow. This chapter identifies schemes for each of the three cities that reflect their topography, their current investment and tolling plans, and the barriers to the political and public acceptability of road pricing that they face.

The proposals are based on a general assessment of transportation in the cities and worldwide experience with road pricing. Before any proposal is implemented, it will be necessary to evaluate it against alternative schemes (and do-nothing scenarios) using travel demand models and detailed spatial information on traffic flows and public transportation services. Road-pricing studies have demonstrated the need for city-specific models to capture the network flow and welfare distributional effects of road investments and tolls—both of which are sensitive to the geographic and demographic characteristics of the area.

As experience in other countries has shown, great care is warranted in taking the first steps in implementing road pricing. Canada has an advantage in being able to learn from other countries as well as from its own experience with Highway 407. Electronic tolling technology is proven, and neither technological hurdles nor costs should stand in the way of road pricing.

Nevertheless, it is difficult to predict on the basis of experience elsewhere whether a given scheme for Canada will be successful. Idiosyncratic features and circumstances appear to have been important in other areas. Singapore has a strong government that is not constrained by politics in the way that Canadian cities are. It also gained long experience with a paper-based area licensing scheme and a transitional road-pricing scheme before launching electronic road pricing in 1998. The toll rings in Norway are part of a long Norwegian tradition of funding transportation infrastructure with tolls, and until recently the main goal has been revenue generation rather than traffic control. London has unusually favorable conditions for an area-based toll, and its successful launch of the congestion charge in 2003 followed years of study. Road pricing in Stockholm also was studied for many years, and there was an unsuccessful attempt to implement it in the 1990s.[89] The sale of Highway 407 to a private consortium in 1999 was encouraged by the financial stringency then faced by the Ontario government.

Flexibility is important in developing an implementation path for road pricing. Cities and provinces develop long-range strategic plans, but often those plans are modified or abandoned due to obstacles, changing priorities, changes of government, and so on. After a short seven-month trial, several changes were made to the Stockholm congestion charge. London's scheme has evolved in several ways. The private operator of Highway 407 surely has more control over tolls than the Ontario government anticipated when it began plans to develop the highway. It is widely argued that because of public acceptability and other barriers, road-pricing schemes should not be designed for perfection, in the sense of attaining the first-best optimum. The proposals here are presented in this spirit.

APPENDIX

The Static Model

Optimal toll

Social surplus inclusive of the premium on toll revenues is

$$W = aN - bN^2/2 - (c + \Gamma dN + e)N + (MCPF - 1) \bullet \tau N,$$

89. The Dennis Package; see Ahlstrand (2001).

where τ is the toll. The user equilibrium condition is $a - bN - \tau = c + \Gamma dN$. The social-surplus maximizing toll works out to be

$$\tau = (\Gamma d + (MCPF - 1)(b + \Gamma d))D^{-1}(a - c) + (b + \Gamma d)D^{-1}e,$$

where $D \equiv (2 \bullet MCPF - 1)b + 2 \bullet MCPF \bullet \Gamma d$.

Calibration of automobile trip demand and user cost functions

Without tolls the equilibrium number of car trips is $N_e = (a - c)/(b + d)$, the generalized trip cost is $p_e = (ad + bc)/(b + d)$, the price elasticity of demand is $\eta = (ad + bc)/b/(a - c)$, and the proportional increase in travel time due to congestion delay is $\%tt = (a - c)d/c/(b + d)$. Solving these four equations yields $a = p_e(1 + \eta)/\eta$, $b = p_e/(\eta N_e)$, $c = p_e / (1 + \%tt)$, and $d = (p_e/N_e)(\%tt/(1 + \%tt))$.

According to City of Montréal (2007, figure 2), in 2003 the number of morning peak trips into Île de Montréal from the rest of the Montréal region was about 184,000. That value was adopted for N_e. No estimates of the price elasticity of automobile travel in the Montréal region could be found. Based on Oum, Waters, and Yong (1992) and Victoria Transport Policy Institute (2007) a base-case value of η = -0.5 was selected, with alternative values of -0.333 and -0.75 for sensitivity analysis.

The generalized cost of a trip was calculated using the formula

$$p_e = VOT \bullet dist/s + (m + v) \bullet dist + park + sdc,$$

where *VOT* is the value of travel time, *dist* is distance traveled, *s* is space mean speed, *m* is the sum of operating and maintenance cost per kilometer, *v* is the variable component of vehicle capital cost per kilometer, *park* is parking cost, and *sdc* is schedule delay cost. The values selected are listed below:

Value of travel time (*VOT*)	C$24.35/hour
Driving distance (*dist*)	10 kilometers
Space mean speed (*s*)	33.3 kilometers/hour
Operating and maintenance cost (*m*)	US$0.131/mile = C$0.081/kilometer
Variable component of vehicle capital cost (*v*)	US$0.063/mile = C$0.039/kilometer
Parking cost (*park*)	C$0.00
Schedule delay cost (*sdc*)	C$2.00

The value of travel time was computed as a weighted average of the 2002 values used for Montréal by Transport Canada (2006c, table 1): C$27.32 for work-related trips (70 percent of peak hour trips) and C$8.48 for non–work related trips (30 percent of peak hour trips). The average was inflated to current dollars using the consumer price index for all items as of November 2007.[1]

In 2001 the mean commuting distance in the Montréal metro area was 7.9 kilometers.[2] For automobile trips into Île de Montréal from the rest of the Montréal region, the distance is likely to be longer. Ten kilometers was chosen as a base-case value, and alternative values of 8 kilometers and 12 kilometers were chosen for sensitivity analysis. The speed limit on most surface streets in Montréal is 50 kilometers an hour. After intersection and congestion delays are adjusted for, the space mean speed is assumed to be two-thirds of that (33.3 kilometers an hour). The values for parameters m and v are taken from Small and Verhoef (2007, table 3.3) and converted to Canadian dollars using a U.S.–Canadian dollar exchange rate at par. Since only about 10 percent of parking in the Montréal region is paid parking, parameter *park* is set equal to zero.[3] Finally, the value of sdc = C$2.00 is based on simulation results in De Palma, Kilani and Lindsey (2005a) and De Palma and Lindsey (2006), which are reviewed in the paper. The resulting generalized trip cost is $p_e = \$10.51$.

The fourth and last calibration statistic, the travel time index, was set at $\%tt = 0.25$, with alternative values of 0.1667 and 0.375 (2/3 and 3/2 as large). With $N_e = 184{,}000$, $\eta = -0.5$, $p_e = \$10.51$, and $\%tt = 0.25$, the demand and user cost function parameters are $a \cong 31.53$, $b \cong 1.14\text{E-}04$, $c \cong 8.408$, and $d \cong 1.142\text{E-}05$.

External cost of a trip (parameter e)

External costs for automobile trips were taken from Parry (2006, table 1). The component values are given in the table below. The cost of global pollution is based on a value of C$50 per metric ton of carbon. By comparison, Transport Canada (2006c, table 4) uses a value of C$29.97 per ton in 1998 dollars, or C$36.73 in 2007 dollars. Despite the larger value used here, reductions in environmental costs account for only a small fraction of the estimated potential benefit of the cordon toll.

Accident (external cost)	US$0.0200/mile = C$0.0124/kilometer
Local pollution	US$0.0133/mile = C$0.0083/kilometer
Global pollution	US$0.0080/mile = C$0.0050/kilometer
Noise	US$0.0010/mile = C$0.0006/kilometer
Road damage	US$0.0000/mile = C$0.0000/kilometer
Total	US$0.0423/mile = C$0.0263/kilometer

1. Statistics Canada (www.statcan.ca/english/Subjects/Cpi/cpi-en.htm).
2. Statistics Canada (2003).
3. City of Montréal (2007, p.139).

Comments

Anming Zhang: Robin Lindsey has written a comprehensive, accessible review of the prospects for urban road pricing in Canada. Applying state-of-the-art knowledge regarding road pricing, he provides a quantitative assessment of the benefits of a cordon toll scheme in Montréal and discusses pricing schemes for Vancouver and Toronto. As populations and economies continue to grow and the demand for transportation and road services continues to rise, the world's major urban centers are increasingly subject to congestion. Road pricing, as a way of charging for the external costs of congestion, has been discussed in the literature since the 1920s. While a number of cities have implemented or are in the process of implementing road pricing, congestion pricing has not been implemented in Canada, nor is there any formal federal policy on tolling.[1] Why has congestion pricing not been implemented in Canada? Lindsey's comprehensive, forward-looking analysis raises five major questions:

—Are major Canadian cities facing congestion problems?

—If congestion is a major problem, why has congestion pricing not yet been called for?

—If congestion pricing is called for, which scheme should be used for each city?

—How should tolls be implemented?

—What should be done with toll revenues?

These questions are related to one another. This comment recapitulates the questions and provides some further discussion. In particular, freight transport implications of road pricing and an additional point on governance structure will be discussed. In Canada, the governance structure and tensions between various levels of government are a complicating factor that aggravates the

I thank Bill Waters for extremely helpful discussion and comments.

1. In the United States, there are a half-dozen high-occupancy toll (HOT) lane projects. Inspired by the success of Singapore, London, and Stockholm, other cities began to consider road pricing seriously. New York, San Francisco, Boston, and Hong Kong are revisiting the idea of road pricing.

already politicized nature of controversial policies such as road pricing; thus, this comment also complements Lindsey's paper.

Are major Canadian cities facing congestion problems?

Despite its vast size, Canada is one of the most urbanized countries in the world: 85 percent of Canadians live in cities or towns (a "town" has a population of 1,000 people or more). Although traffic congestion is minimal outside major urban areas, it is increasingly noticed in large cities. Table 1 reports the growth rates of population, GDP, and vehicles in the six largest Canadian urban areas in recent years and shows that population grew faster in all these cities, except Montréal, than it did for Canada as a whole. Montréal's population grew at a rate of 3.0 percent between 1996 and 2001 and 5.3 percent between 2001 and 2006, below the national average for those periods (4.0 percent and 5.4 percent respectively). Note also that the GDP growth rates in Montréal and Toronto were lower than the national average in recent years. On the other hand, the number of vehicles has increased substantially in Canada.

A glance at these data does not seem to point immediately to a serious congestion problem for major cities. Here, Lindsey's analysis is useful in demonstrating that congestion costs in the three largest Canadian urban areas—Toronto, Montréal, and Vancouver—has reached a trigger point for some serious action. His rigorous cost-benefit analysis on Montréal, in particular, shows that the benefits from road pricing are considerable and that congestion relief would be the largest potential benefit.

While Lindsey's analysis focuses mainly on passenger traffic, another way to prompt discussion of road pricing is to consider the freight transport challenges that these cities are facing. According to General Accounting Office (2003), from 1993 through 2001 truck traffic on urban highways in the United States increased more than twice as much as passenger traffic. Given existing urban highway congestion, that implies that freight traffic was contributing to worsening congestion at a faster rate than passenger traffic. As Lindsey shows, Vancouver, Montréal, and Toronto all have significant freight traffic, with Vancouver and Montréal being major North American gateways and Toronto an important link in Canada-U.S. trade. Take Vancouver, Canada's largest container port, as an example. Its container throughput has grown at an annual rate of 12 percent since 1980—the corresponding figure for Montréal is 6 percent—which is faster than the growth rate of U.S. ports on the West Coast. Despite several major expansions, congestion is still a major concern, both at the port and on the local roads. The latter is caused by trucks moving freight between terminals and around the region. It is also caused by local movement of these

Table 1. Population, GDP, and Vehicle Growth in Major Canadian Urban Areas
Percent

Urban area	*Population (2006)*	*Population growth (1996–2001)*	*Population growth (2001–06)*	*Average annual GDP growth (2002–07)*	*Vehicle growth*[a] *(1999–2006)*
Toronto	5,113,149	9.8	9.2	1.34	15
Montréal	3,635,571	3.0	5.3	2.62	16
Vancouver	2,116,581	8.5	6.5	3.44	17
Ottawa-Gatineau	1,130,761	6.5	5.9	2.72	15
Calgary	1,079,310	15.8	13.4	3.83	35
Edmonton	1,034,945	8.7	10.4	3.09	35
Canada	31,612,897	4.0	5.4	2.83	18

Source: Statistics Canada (2008); Conference Board of Canada (2008).
a. Figures are for the provinces to which these cities belong.

containers: about 20 percent of container volume moving through the Port of Vancouver is local traffic and thus relies on trucks for final delivery.[2]

Truck traffic in Vancouver is expected to increase by 50 percent between now and 2021, generated primarily by the Port of Vancouver (at its Deltaport container terminals), Fraser Surrey Docks, and the Vancouver International Airport.[3] Vancouver's current share of container volume for the North American West Coast ports—Vancouver, Seattle, Tacoma, Portland, Oakland, Los Angeles, and Long Beach, which together accept 85 percent of North America–bound containers from Asia—is 8.5 percent, but the goal is to reach 12 percent by 2020, despite the opening of new container facilities at the port of Prince Rupert north of Vancouver.[4] Truck movements resulting from additional container traffic can have a significant impact on local traffic conditions and social costs. For example, Berechman (2007) finds that the additional highway traffic due to a (modest) increase of 6.4 percent in container throughput at the Port of New York would induce annual social costs ranging from $0.66 billion to $1.62 billion—more than 60 percent of which would be from congestion costs (drivers' discomfort as well as the time loss due to traffic conditions, both of which are a function of increasing road volume-to-capacity ratios). On the other hand, congested roads could also hinder the port development. For instance, growth at the ports of Los Angeles and Long Beach has been hindered by road congestion in the greater Los Angeles area. Time-series data in Zhang (2008) show that the correlation of container throughput at these two ports with all the road congestion measurements for the Los Angeles area is negative—and highly sta-

2. Zhang (2008). Asian countries are the driving force behind Vancouver's container growth, with China accounting for 62 percent of the Asian share in 2006.

3. See the Gateway Program website (www.th.gov.bc.ca/gateway/).

4. Zhang (2008).

tistically significant. While a passenger may be able to choose between various means of transport (and different times of the day) for his or her travel, goods sometimes can be delivered only by road, on a tight schedule. Since Vancouver is the main gateway for Canada, it needs to develop and maintain an efficient road network. In this case, road pricing could help both the gateway and local economic development.

If congestion is a major problem, why has congestion pricing not yet been called for?

In a recent study, Appleton and others (2007), data were collected on public policies that have a bearing on congestion reduction—including, among others, trip reduction programs; discounted bus pass for city employees and students; transit vehicle maintenance expenditures per capita (as a proxy for public support for public transit); and housing starts in row and apartment units (urban planning policy)—for the twenty-nine largest census metro areas (CMAs) in Canada. Toronto, Montréal, and Vancouver (and also Ottawa) were ranked among the very top Canadian CMAs for most of the policy initiatives, so it appears that policy measures other than congestion pricing have been undertaken by these highly congested cities. Therefore one might wonder why, if congestion is a major problem, "congestion pricing" has not been called for. Lindsey's paper has a good discussion on the factors—for example, political acceptability—that underlie the unpopularity of congestion pricing. It further indicates that some of those factors are changing in favor of congestion pricing in Canada. First, there is mounting concern about traffic congestion and climate change. While the two traditional rationales for road pricing—internalizing the external costs of congestion and raising revenue—have not been popular with drivers, more recently there seems to be less resistance to tolls as the concept has been extended to include charging for the external costs of accidents and environmental impacts. Second, there is accelerating momentum for road pricing in the United States. Third, successful congestion pricing in London and Stockholm offers a possible model for Canada.

With respect to the third factor, it is also worthwhile to note two important differences. First, according to Transport for London (2003), in 2001 more than 1 million people entered central London (an area wider than the charging zone) between 7:00 a.m. and 10:00 a.m. (peak hours) on a typical weekday and more than 85 percent of the people used public transport. But the corresponding ratios are much smaller for both Montréal and Vancouver, where similar cordon toll schemes are proposed. Second, although the idea of charging drivers was politically unpopular in London, there were recurrent calls for congestion tolls prior to the implementation of the congestion toll. That has not been the case in either Montréal or Vancouver. Those differences are likely to add to the difficulties of implementation in Canada.

If congestion pricing is called for, which scheme should be used for each city?

Lindsey's paper contains good discussions of each of the following charging schemes: area-based schemes (such as cordon toll); tolling a network of roads; and tolling individual roads or lanes (facility-based tolls). Within each scheme, variable/dynamic charges are compared with flat charges. Moreover, schemes are proposed for each of the three cities that reflect their topography and the barriers to the political and public acceptability of road pricing and that build on their current road investment plans:

—Montréal: variable toll cordon around Montréal Island

—Vancouver: variable tolls on a network of major bridges and tunnels

—Toronto: conversion of existing HOV lanes to dynamically priced HOT lanes and construction of new lanes as HOT lanes.

While people have talked vaguely for years about the prospects of road pricing in these three cities and others have made various suggestions for introducing tolls in each city, no formal analyses are yet publicly available. Lindsey's paper is the first study on congestion pricing schemes for the three areas that is based on both the experiences of other countries and the results of recent academic research. There is a growing literature on road pricing in a transportation network—see both Small and Verhoef (2007) and Lindsey's paper for references—to which Lindsey himself is a major contributor. The paper, which also contains a lot of useful information about important link characteristics and detailed documentation of recent policy developments in the three cities, is highly recommended reading for anyone who is interested in road pricing issues in Canada (see also Lindsey 2007).

I agree with the author that variable tolls are better than flat tolls, with the former charging drivers at peak hours only (meaning that they are congestion tolls). Whether the variable tolls should be "dynamic" (based on the level of congestion or distance traveled) could be considered a matter of implementation strategy; it might be better to start with just variable tolls. For Montréal, with the cordon toll scheme, perhaps the most important distinction is between drivers who cross the cordon from the suburbs and those who do not; therefore, the distributional effects of the toll on the two groups may need more examination. For instance, fiscal competition between Montréal Island and the suburbs is likely. As a result, a "tax exporting" toll may arise (see, for example, Ubbels and Verhoef 2007). Here, more analysis (for example, of in/out resident proportions; traffic flows) may be conducted to assess the nature of such interjurisdiction competition. Given interjurisdiction competition, perhaps pricing schemes should be determined by broader regional policies instead of primarily local policies.

For Vancouver, the author proposed a cordon-like variable toll scheme on major bridges and tunnels—the number of bridges and tunnels in Vancouver (24) is comparable with that in Montréal (18). It seems to me that in general, the case for a cordon toll scheme for Vancouver is not as strong as for Montréal. First, Lindsey noted that use of public transit is less in Vancouver, in percentage terms, than in Montréal or Toronto, but that may be influenced by city size. The share of transit ridership tends to rise from the smallest to the largest cities, owing largely to the impossibility of relying on cars as cities become larger. Vancouver has noticeably higher transit use than other North American cities of comparable size. Second, while bridges and tunnels may be used as the location for a cordon or screening, their impacts on unpriced alternate routes are a concern. Over the last decade, jobs became more dispersed over the greater Vancouver regional district (GVRD) and there has been a corresponding migration of population, especially up to the Fraser River (for example, Coquitlam) and Surrey. I therefore concur with Lindsey that Burrard, Granville, and Cambie bridges should not be included as the first priority of tolling, on the grounds that they no longer are considered a route to outer regions but essentially a part of downtown itself. (And although Vancouver's downtown population is experiencing some of the fastest growth in the GVRD, downtown congestion is not really getting worse.) In the longer term, there is a need for a full-fledged road pricing scheme applying to all bridges and tunnels as well as some other major corridor choke points. The scheduled tolling of the Port Mann Bridge and Golden Ears Bridge may give us the (political) excuse to say that including tolls on other bridges and tunnels is overdue.

How should tolls be implemented?
What should be done with toll revenues?

In Lindsey's paper, proposals for implementing road pricing in the three cities also present two general policy questions: how should tolls be implemented and what should be done with toll revenues? With respect to revenues, there may be a need, in order to improve public acceptability, for the government to make a credible promise that the revenue generated by the tolls would be refunded to users (drivers) in terms of road and related infrastructure; allocated to the public transportation budget; and used to reduce other taxes. The paper has a good discussion of the first two uses. If road expansion and public transportation are financed by other funding sources, the possibility that a large amount of revenue could be obtained from road pricing (with a 4:1 revenue-cost ratio or more in some of Lindsey's Montréal and other simulations) might lead people to suspect the government's motives and to regard road pricing as a mere revenue-raising device. Given that politicians have zero credibility in saying that tolls are not just a tax grab, proposals for tolls may be accompanied by specific suggestions of what other taxes could be cut to make the new tolls revenue neutral. Elected officials should not just make vague recommendations to "cut something by some amount somewhere"; they should say that they will "cut gas taxes or reduce property taxes by X percent." People still may not trust them, but at least such an approach might get people thinking that the existing tax structure is not optimal and that there would be some benefits from reorienting road pricing. (Of course, there is still the danger that vested interests would benefit more than others from specific tax reductions.)

With respect to implementing tolls: the government can start with modest tolls, which need not be the first-best or even the second-best option. Existing studies (of tolls in California, London, and Stockholm) indicate that people seem to respond to even small tolls. Plus, people have been responding to the wrong tax structures for the last fifty years. Once people become more used to tolls, greater incentives (or disincentives) might be introduced to reduce congestion and improve efficiency further. This staged approach may preclude making any firm promises at the initial stage of implementation. In the case of London, to appease fears that the congestion charge would just be an additional tax, Mayor Ken Livingstone said in 2002 that the toll was likely to remain unchanged for a decade. In July 2005, the mayor broke his promise that the congestion charge would not change and increased it by 60 percent, giving rise to a new controversy.

Does the governance structure need to be changed?

Lindsey does mention the various levels of government in Canada—federal, provincial, and municipal—and their implications for implementing road pricing. The discussion might not have been stressed enough, especially in answering the question of why congestion pricing has not yet been implemented in Canada and why, unlike in Britain (Nash 2007) and the United States, there is no formal federal government policy on tolling. The division of economic and political power between federal and provincial governments is much more pronounced in Canada than in Britain (where no provinces or states exist, only counties) and the United States, where the federal government's powers are generally larger than those of the states. In Canada, provinces guard their powers jealously and resent federal intrusion. In the United States, the federal government has little legitimate reason to be involved in urban transport, but it finds ways to be involved and to offer support, probably because the health and viability of cities is vital to the overall economic well-being of the nation. But a federal presence in urban transport is more difficult to bring about in North America, especially in Canada, than in Britain and most of Europe. Furthermore, I think that it can be said that the power differential between province/state and municipalities is greater in Canada than in the United States. Municipalities have limited taxation powers in Canada; for example, cities cannot levy income taxes. That is, although cities are the source of many economic challenges, including urban transportation, the federal and provincial governments hold the powers of taxation required to deal with those challenges. The subservience of municipal governments is a major handicap in dealing with urban transportation problems. For example, TransLink has the nominal power to impose vehicle levies, but when it tried to do so, the province refused to approve a levy because it did not want to face the wrath of voters.

Institutional reform might be undertaken so that, for example, a single institution (authority) manages the road network for the region. In Vancouver, bridges and tunnels are now controlled by various owners or operators: the provincial Ministry of Transportation, Vancouver International Airport, various local municipalities, and TransLink. A similar situation occurs in Montréal, although perhaps to a lesser extent. The pricing processes and approvals now shared and administered by various levels of government could be streamlined under this single authority, which would have further responsibility for both charging and spending decisions. Users should also be involved in decisions on charges and expenditures.[5]

This discussion indicates that political will is perhaps the most important requirement in carrying through any road pricing initiative in Canada. At the moment, the federal government does not have a formal policy on tolling. Political will also is needed in order to remove institutional and administrative barriers, which might require changes in legislation and administrative structures. Political will may be built up over time by many things—circumstances, outside influences, changing ideas, shifting technologies, new research findings, and so on. Academic research on the benefits of road pricing such as Lindsey's—or on the costs of doing nothing—therefore is extremely important. Furthermore, research can be effective in influencing the attitudes of policymakers and the public in the policymaking process, but first it must be

5. CTAR (2001).

effectively disseminated—it must be put before the appropriate decisionmakers and the public, and it must be easily accessible. In coming years, congestion pricing for Canadian roads will certainly be a subject for discussion. Lindsey has provided us with a well-reasoned introduction to the discussion, and his paper should inspire further healthy debate.

José A. Gómez-Ibáñez: Congestion tolls are collected in only a few of the world's cities—most notably Singapore and London—despite the fact that economists have been advocating their use for many decades. Proponents of congestion tolls often blame three obstacles, or challenges. The first is the method or technology for collecting the tolls. Congestion tolls should vary by location and time of day as traffic congestion varies, and the need to vary tolls with congestion makes toll collection potentially more complicated and problematic for both highway agencies and motorists. The second is the geography and road network of a metropolitan area. Collecting congestion tolls is more difficult when congestion is spread throughout an area, not concentrated at a few bottlenecks or in well-defined zones, and when travelers lack reasonably convenient alternative routes or modes of transportation. The third challenge is gaining political support. Economists can demonstrate that the benefits of congestion charging, when it is properly implemented, exceed its costs. The basic problem, however, is that those benefits and costs accrue to different people. The winners typically are motorists who place a high value on saving travel time and the recipients of the government services financed by the toll revenues. The losers are the motorists who are forced to shift to a less convenient time, route, destination, or mode of transportation as well as motorists who continue to take congested routes but do not value the time savings by as much as cost of the congestion toll. It is difficult to arrange some form of compensation from the winners to the losers that does not undermine the incentives of the scheme.

These three challenges—collection technology, geography, and politics—interact. The geography or network affects the technology, for example, in that it may be possible to use a simpler or less costly collection scheme if congestion is concentrated in a well-defined area or on a few key roads and bridges. And the technology and geography affect the possibilities for gaining political support. Having a more difficult geography and a more complex and costly collection method may reduce the benefits of a congestion charging scheme relative to its costs; it may even make the scheme, on net, a losing proposition. The lower the benefits and the higher the costs, the more difficult it will be to design a congestion charging scheme that is politically acceptable.

Robin Lindsey considers how congestion charging might be introduced in Canada, a difficult prospect considering that Canadian motorists are even less accustomed to paying to use highways than U.S. motorists are, much less paying tolls that vary with the level of congestion. In addition, Canadian metropolitan areas are not terribly congested, which reduces the perceived need for a remedy. Lindsey proposes very different schemes for introducing congestion tolls in Canada's three largest cities—Montréal, Vancouver, and Toronto—responding cleverly and thoughtfully to their particular circumstances. In the cases of Montréal and Vancouver, Lindsey's primary consideration is geographic. He takes advantage of the fact that Montréal's congestion is concentrated on the island of Montréal to suggest a cordon charging scheme in which congestion tolls would be collected on the twenty-plus bridges and tunnels that provide access to the island. Downtown Vancouver is not on an island and its suburbs are nearly as congested as the center, which makes a cordon scheme less attractive. But Lindsey exploits the fact that the metropolitan area is crisscrossed with rivers and inlets to propose collecting congestion tolls on all the major bridges.

For Canada's largest city, Toronto, Lindsey's concerns are largely political rather than geographic. Unlike Montréal and Vancouver, Toronto does not have a well-defined central area that could be easily cordoned off or an extensive system of bridges, tunnels, or other bottlenecks that would warrant toll collection. But Toronto has announced plans to build a network of more than 450 kilometers of high-occupancy vehicle (HOV) lanes, which Lindsey argues should be built as high-occupancy toll (HOT) lanes instead. HOV lanes are reserved for the exclusive use of buses and multiple-occupant vehicles and generally are not tolled. HOT lanes also are free for buses and multiple-occupant vehicles, but single-occupant vehicles can use them too if they pay a congestion toll. Building a network of HOT lanes is unlikely to be as effective in reducing congestion as tolling Toronto's many existing highway lanes. But Lindsey wants to exploit the fact that there is less opposition to collecting tolls on new highways than existing highways, particularly if motorists believe the new facility would not have been built without the toll revenues. The advantage of collecting tolls for a new highway is that the motorists who bear the toll also benefit through their use of the new highway.

While Lindsey effectively addresses the challenge of gaining political support in Toronto, he offers no convincing strategy for building support in Montréal and Vancouver, where most of the facilities that he proposes to toll are not new. The fact that Toronto is building so many new facilities is unusual. Congestion would be less of a problem if it were easy to expand highway capacity in major metropolitan areas. Constructing a new urban highway or widening an existing highway may be attractive to the motorists who would use it, but it usually provokes intense opposition from households and businesses in or near the proposed right of way. Toronto's proposed HOV lanes may be less controversial with owners of abutting properties and relatively inexpensive to construct because they would be built largely in the medians of existing expressways. But for most metropolitan areas, building new highways is not a realistic solution to congestion. The need to address the political challenge is becoming more important, moreover, because improvements in technology are rapidly reducing the constraints of toll collection and geography. Soon the only major obstacle will be political.

Improvements in Toll Collection Technology

The difficulty of collecting tolls that vary by location and time of day was always somewhat exaggerated. Early opponents raised the specter of toll booths scattered across the city, staffed by an army of toll collectors who delay motorists as they pay their tolls. But in 1975, Singapore, the first city to adopt congestion tolling, showed that collection costs and delays could be kept to a minimum with a simple system of paper windshield licenses. Motor vehicles entering the central area of Singapore during the morning and later (in 1989) during the evening rush hours were required to display a daily or monthly license, which could be purchased at kiosks on the main approaches to the central area; the licenses were color coded by month and displayed a date in bold numerals so that police or other enforcement agents could see at a glance whether they were valid. The paper license method did have limitations, in that Singapore authorities were unwilling to vary the license fee within rush hours or to create multiple cordons with different fees for fear of confusing motorists and complicating enforcement. But Singapore's congestion charging scheme proved effective and practical despite those constraints.

The technology used for toll collection has evolved rapidly since 1975, first with the development of electronic toll collection through roadside beacons that communicate with in-vehicle tags. Beacon and tag systems were originally pioneered in the early 1980s by toll road operators in Europe and the United States who were more interested in reducing expenditures on staffed toll booths than in making it easier to vary tolls by time of day or location. Field trials in Hong Kong in the mid-1980s showed that beacons and tags could accurately collect charges on congested urban streets, although city officials ultimately decided not to adopt congestion tolls. Singapore converted from paper licenses to an electronic tag and beacon system in 1998, a change that allowed for more flexibility in locating charging points where congestion was located and to vary charges by hour over the course of the day.

The next development was to automate enforcement by using cameras to photograph the license plates of vehicles passing a charging point and employing software to read the license plate numbers. Video enforcement schemes were pioneered by several Norwegian cities that implemented cordon tolls in the mid-1980s and wanted to allow motorists who did not have an electronic tag the option of paying cash at unmanned toll booths. The automated video enforcement worked, although the Norwegian cordons were too poorly located and the toll levels too low to significantly affect congestion. When London adopted congestion pricing in 2003, it chose automated video enforcement instead of a tag and beacon system because the video system could be implemented more quickly and had less visual impact on London's historic streets. Video cameras can be mounted unobtrusively on light poles or on buildings, while at that time beacon systems required unsightly overhead gantries. An added advantage is that video enforcement does not require all vehicles entering an area to be equipped with an electronic tag. The license plate numbers of cars traveling in central London are compared with plate numbers of motorists who have paid a fee to enter central London for that day or month, and violators are fined. The fee of £5 per day (later raised to £8) can be paid by Internet, by telephone, at machines in parking lots, and other sales points. Motorists who enter the central zone unexpectedly have up to midnight the same day to pay the fee without incurring a fine.

The next likely technological development is the use of global positioning systems (GPS) to collect congestion tolls. The prices of on-board GPS devices have dropped rapidly, and their use for navigation is becoming more common. In 2005 Germany began using GPS devices to collect tolls from heavy trucks using its 12,000 kilometer network of autobahns. The tolls are based on the distance the trucks travel on the autobahns; the GPS devices identify when the trucks are on the network and how far they travel. It is more difficult to locate a vehicle accurately in urban areas, however, because buildings can reduce the number of satellites in view and dense street networks increase the potential for mistakes. Moreover, the level of accuracy required for tolling is much higher than is acceptable in systems used for vehicle navigation, since inaccurate bills generate costly appeals and ill-will. Nevertheless, periodic field trials by Transport for London (TfL), the agency that administers London's congestion tolling scheme, show that GPS devices have been improving rapidly (table 1). When

Table 1. Improvements in the Accuracy of On-Board GPS Units in TfL Trials

Error in meters

Vendor	*Average error*	*Standard error*	*75th percentile error*	*95th percentile error*	*99th percentile error*	*Maximum error*
Average vendor in 2004 trials	9.70	14.60	14.00	28.00	57.00	500
Average vendor in 2006 trials	6.71	8.90	8.22	20.51	38.35	226
Best vendor in 2006 trials	5.11	6.48	6.36	14.35	26.17	166

Source: Transport for London (2006).

TfL asked vendors to submit on-board GPS devices for testing in London's streets in 2004, the average reading was off by 9.7 meters and the 99th percentile reading was wrong by 57 meters. When TfL repeated the testing in 2006, the vendors had an average error of 6.7 meters and a 99th percentile error of 38 meters, while the best-performing vendor had an average error of 5.1 meters and a 99th percentile error of 26 meters.

Older technologies are improving as well. London is considering adding a tag and beacon system, for example, because improvements in focusing the electronic beams mean that the beacons no longer need to be mounted on gantries that span the street. The current video system probably would be retained to detect violators without tags or perhaps to provide a payment option for occasional users who would prefer not to purchase a tag. But the tag and beacon system would provide a more convenient method of billing and payment for regular users, and it would simplify London's eventual transition from a single daily charge for entering the central area to charges that vary by the number of times a vehicle passed a charging point.

Politics and the Exception of London

While technology is making it less costly and more convenient to collect congestion tolls, is tolling also becoming more politically acceptable? The fact that for nearly three decades Singapore was the only major city to implement congestion tolls has reinforced the idea that tolls are politically difficult to implement. Automobile ownership was still low when Singapore first imposed congestion tolls. More important, Singapore has been ruled by a single political party since its independence from Britain, in part because Singapore's election rules and libel laws make effective political opposition difficult and risky. London's adoption of congestion tolls in 2003 shook the conventional wisdom because auto ownership is high and politics are hotly contested in the United Kingdom. If London can adopt congestion charging, perhaps large cities in North America and Europe will follow suit.

The basic political problem—that some people gain while others lose—applies to congestion charging in London. The London scheme was remarkably successful in reducing traffic volume and increasing travel speed in central London. As a result, the TfL estimated that the scheme generated a net gain to society of £50 million in its first full year of operation, as shown in table 2. Proponents of congestion tolling were somewhat disappointed, however, in that the net gain was less than one-third of the £180 million in congestion charge fees that were collected. The modest net gain was due primarily to the need to spend roughly £115 million for scheme administration, including £90 million in fees to the contractor that implemented the charging scheme for the government, £20 million for additional bus services, and £5 million for TfL oversight.

As important as the size of the net benefit is the fact that the benefits and costs of the London scheme were unevenly distributed, with some parties winning and others losing. The extent to which the distribution was uneven is masked by TfL's consolidation of car, taxi, van, and truck users into groups for reporting purposes, but it is still possible to identify the most obvious winners and losers. The biggest winners are almost surely mass transit users, who netted roughly £95 million because the government had committed itself to spending its net revenues of £65 million to support transit and because bus riders gained an additional £30 million in time and reliability savings. The next-biggest winners were taxi operators and their customers because taxis were exempt from the license fees and operators and customers probably benefited from approximately one-third of the £110 million in time savings that TfL estimated for cars and taxis together.[1] Delivery van and truck operators also may have gained—or at least did not suffer greatly—because they paid the same £5 daily fee as car drivers but probably traveled more miles in, out, and through the central area during the course of a day and thus benefited significantly from reduced travel times. Presumably the biggest losers were car users, who appear to have lost roughly £82 million. Car users benefited from approximately two-thirds of the estimated £110 million in time savings for cars and taxis together. But car users paid approximately two-thirds of the £180 million in daily license fees and of the £15 million in charge payer compliance costs if they continued

1. Two hundred thousand cars and taxis entered central London between 7:00 a.m. and 6:30 p.m. in the spring of 2003, of which roughly two-thirds (133,000) were cars and the rest taxis (Gomez-Ibanez 2005, p. 18).

Table 2. TfL's Benefit-Cost Analysis for Congestion Charging in Central London for Various Parties, FY 2003–04

Party	*Benefit or cost in £millions per year*
Government	
TfL administration	-5
Contractor	-90
Additional bus service	-20
Fee revenue	+180
Subtotal	+65
Bus riders	
Time savings	+20
Reliability benefits	+10
Subtotal	+30
Accident victims	
Accident reduction	+15
Subtotal	+15
Car, taxi, van, and truck users	
Time savings, car and taxi	+115
Time savings, van and truck	+20
Reliability benefits	+10
Vehicle operating savings	+10
Charge-payer compliance costs	-15
Disbenefit to car occupants who transfer to public transport	-20
Fee revenue	-180
Subtotal	-60
Society in general	+50

to drive,[2] or they suffered £20 million in added inconvenience if they switched to public transportation.

Several factors allowed London to implement congestion pricing, despite the fact that the scheme essentially involved a substantial net redistribution of resources (both money and time) from car users to mass transit users and taxi operators and passengers. London is unusual in that even before congestion charges were imposed, 85 percent of people working in Central London already commuted by public transportation, so that car users, who stood to lose, already were a small minority. Moreover, only 73,000 households lived in Central London, so that it was easier to accommodate the political pressure to exempt residents' cars without seriously undermining the effectiveness of the scheme.

2. One hundred ninety-five thousand cars, trucks, and vans liable for a congestion fee entered central London between 7:00 a.m. and 6:30 p.m. in the spring of 2003, of which roughly two-thirds (133,000) were cars and the rest trucks and vans (Gomez-Ibanez 2005, p. 18).

The central areas of most North American and European cities have far more automobile commuters and residents than London does.

London is also unusual in that the mayor, Ken Livingston, had exceptionally strong incentives to pursue congestion pricing. Conservative prime minister Margaret Thatcher abolished the elected government for metropolitan London in 1986, in part because she believed that the governments of the thirty-three boroughs and cities that made up Greater London could do an adequate job of representing metropolitan interests but also because the Greater London Council had been a stronghold of the Labor Party. When the Labor Party won control of Parliament again in 1997, it restored elected government by creating the Greater London Authority (GLA) in 1999. The GLA is responsible for little besides transportation—education, police, and most other services are the responsibility of the national government—so transportation is about the only way a mayor can make his mark. The architects of the GLA had given it the power to establish congestion charges because London had tried almost every other solution to congestion over the previous forty years, with little success. In addition, Mayor Livingston did not have a strong relationship with the national government at the time, and thus he could not rely on its financial assistance to improve London's transportation system. (Livingston had been a longtime member of the Labor Party, but ran for mayor as an independent after Labor Party leaders rigged the nominating rules to favor a candidate who fit the more conservative image that they were trying to project at the time.) Congestion charging promised to improve traffic flow and generate financial resources for public transportation that Livingston was unlikely to find elsewhere. He campaigned on congestion charging in the 2000 mayoral election, and he made certain that the scheme was up and operating by 2003 so that citizens would have one year of experience with the system before he would have to run for re-election in 2004.

Mayor Livingston and the TfL also carefully designed and implemented the scheme to enhance its political acceptability, even at the expense of undermining its effectiveness. The simple central area charging scheme and video enforcement were adopted to ensure that tolling would be in place and any implementation problems resolved well before the next election. To forestall organized opposition from various groups, the proposed truck fee was dropped from £15 to £5, residents of the central area were given a 90 percent discount, and taxis were exempted entirely. And Mayor Livingston spared little expense to ensure that compliance was easy and enforcement accurate so that motorists would not have additional reasons to object. For example, administrative costs for the scheme were high in part because Livingston insisted on having many different ways to pay the fees and required that the video image of each violator's license plate be manually checked before notice of a fine was sent out.

Although London's circumstances—few motorists and residents, a mayor with little else to campaign on, and superb implementation—are unlikely to be replicated in Canadian cities (or elsewhere), it still may be possible to win political support for congestion tolling. Most efforts to date have sought to design ways to compensate motorists without undermining the scheme's incentives. In the 1980s, for example, Hong Kong proposed reducing the city's considerable motor vehicle excise taxes and annual license fees when it introduced congestion charges so that the net effect would be revenue-neutral for the average motorist. Most of the motorists who drove in congested places would be worse off relative to their peers, an unavoidable consequence if the incentives of congestion tolls were to be retained, but at least they would receive some relief through lower excise taxes and license fees, and motorists as a group would be held harmless. The plan was never implemented, however, in part because Hong Kong motorists did not trust their government to lower the auto excise taxes and fees as promised and also because the scheme became caught up in the politics of Hong Kong's pending return to Chinese rule.[3]

There may be other strategies to make tolling more politically acceptable. For example, King, Manville, and Shoup (2007) argues that if compensating the motorist is too difficult, it may be better to build a group of supporters with enough interest in the scheme to offset the motorists' influence. They suggest assigning congestion toll revenues to the communities along the right-of-way so that they will have a strong and obvious interest in supporting the policy. Whether that would work is unclear, but more thought should be given to the challenge of developing political support, which is fundamental to the prospects of congestion pricing in Canada and elsewhere in North America and Europe.

3. Gomez-Ibanez and Small (1994).

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