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Underpriced and Undervalued

Exploring curbside pricing policies in Toronto

Mark Stout

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Executive summary

Curbside competition is intensifying. In Toronto, as in all big cities, travel behaviours and transportation patterns are changing. As such, the City of Toronto has recently developed a Curbside Management Strategy to improve the allocation and usage of this space, and to ensure people can access the curb where and when they need it. This city policy includes a recommendation to explore variable curbside parking pricing options, which is the focus of this report.

The last decade has resulted in great shifts in transportation and curbside use: mobile app-supported ride-hail, ride-share, and microtransit; micro-mobility options, such as e-cargo bikes and e-bike-shares; continued advancements in an equitable and efficient redistribution of street space from single occupancy motor vehicles toward walking, cycling, and public transit in dedicated curb lanes; responses to the current pandemic with patios and public spaces occupying curbside locations; the strategic reduction of off-street parking requirements for new developments; and increased doorstep package deliveries. Additionally, Toronto is experiencing land-use intensification through the further introduction of multi-residential and mixed-use buildings, increasing demand for access to the curbside, day and night. Toronto needs better ways to manage this intensifying curbside competition; the city must improve how it manages its biggest public space — *its streets*.

The need for parking infrastructure increases and decreases throughout the day and across the geography of the city, depending on traffic and access requirements. To maintain balance in the parking system, sophisticated tools are needed to handle peak demands. This is essential as parking policy is a powerful influencer of city look and feel, and how people travel within cities; it is more significant than almost anything else. A more nuanced curbside parking policy can address peak-period parking congestion, more evenly distribute the demand on the streets, and meet overall parking policy objectives.

An econometric and traffic model was developed to examine three different on-street parking pricing policies to assess their effectiveness in addressing the curbside challenges facing Toronto today: hourly pricing, which is the existing policy in Toronto; progressive hourly pricing, where prices increase with the duration of the stay; and time-of-day pricing, where prices increase during peak demand. The study did not model dynamic pricing, where parking prices are matched to parking demand in real time. Each pricing policy was evaluated based on their effectiveness to manage curbside

competition, alleviate congestion, and reduce transportation-related greenhouse gas emissions. Further, policies were evaluated in peak-period conditions (morning rush hour) and off-peak-period conditions.

The Pembina Institute finds that the existing policy — hourly pricing — is failing to effectively manage high-demand curbside parking on some streets in the downtown core, with some areas overutilized, showing 80-100% occupancy during peak hours.

Based on our research findings, the Pembina Institute recommends moving to the implementation of a progressive hourly pricing policy. Some of the benefits of progressive hourly parking pricing:

- Keeps curbside parking occupancies lower. In the peak period, progressive hourly pricing reduces the average occupancy rate by 7% compared with the existing policy. Lower occupancy makes parking easier to find.
- Reduces "cruising" for parking. Vehicles searching for parking often have to circle the block, wasting time and emitting greenhouse gases. In the peak period, progressive hourly pricing reduces the number of vehicles that cruise and search for available parking by almost 40%, compared to hourly pricing (existing condition).
- Lowers the total network travel time and carbon emissions of all vehicles in the network.
- Increases the collected parking revenue.

Based on our review of implementation practices of other jurisdictions, such as Albany, New York, Aspen, Colorado and Antwerp, Belgium, the City may want to consider **implementing a pilot project** in a targeted area prior to full program rollout to resolve any unintended outcomes. Best practices show that developing a comprehensive public education and communications campaign on changes to parking policies is key to successful implementation.

Although this study did not evaluate the potential impacts of dynamic pricing in Toronto given the additional analytical methods needed for dynamic pricing compared to the other three pricing policies, and resource limitations, research and real-world applications show that this policy approach, like progressive hourly pricing, can also be an effective way to manage curbside activities. Where there is an opportunity to do so, the City may want to consider **evaluating and comparing the effectiveness of a dynamic parking pricing policy** in Toronto through an additional modelling activity using similar data to those used in this study.

1. Introduction

Curbside pricing is an urban-transport demand management tool that is growing in use in major cities around the world. Beyond managing the limited curbside space for on-street parking, it is a tool that can balance and effectively provide for other urban street uses like curbside cycling facilities, dedicated transit lanes and stops, parklets, restaurant patios, commercial or delivery loading zones, etc. Further, some Canadian and American cities are beginning to remove off-street parking requirements in new developments — similar to the City of Toronto's current 2021 review of parking requirements in Zoning By-law 569-2013 — which may increase on-street parking demand. That means policy tools are needed to manage this finite public resource, our city streets.

The City of Toronto developed a Curbside Management Strategy (CMS) in 2017 with a goal to manage congestion, encourage curbside activity that supports economic activity, and support various curbside functions. The strategy offers a high-level policy framework, principles, and implementation plan that aligns with existing City plans and policies such as the Official Plan (Chapter Two) curbside management policy.[1] The CMS establishes a framework to assess new curbside initiatives, evaluate trade-offs with competing uses, and ensure an equitable allocation of curb space. One of the CMS's recommended implementation initiatives is to investigate variable pricing options for the curbside.[2] To this end, this study examined curbside pricing through a literature review, jurisdictional scan, and modelling of three different curbside pricing policies for Toronto.

1.1 Purpose and study methodology

The Pembina Institute conducted a study of pricing policies that would address the curbside challenges facing Toronto today. The purpose of this project was to evaluate the effectiveness of curbside pricing policies to meet the overall policy objectives of managing curbside competition, alleviating congestion, and reducing transportation-related greenhouse gas emissions (GHGs). Research shows that curbside pricing

[1] City of Toronto, *Official Plan,* April 2021, chapter 2 section 2.4 p. 2-36. https://www.toronto.ca/wp-content/uploads/2017/11/9048-cp-official-plan-chapter-2.pdf

[2] City of Toronto, *Curbside Management Strategy: Final report*, prepared by IBI Group (2018), "Recommended Policy Approach," Section 7.3.2.

mechanisms can be used to manage the curbside supply, reduce cruising to find parking spaces, and thus reduce carbon emissions.

The Pembina Institute conducted a literature review and jurisdictional scan of various on-street parking pricing policies, and analyzed three pricing policies using an econometric and traffic model to understand the environmental, transportation and revenue impacts:

- **Hourly pricing** (the existing pricing policy in downtown Toronto)
- **Progressive hourly pricing** (the price escalates with longer time parked; e.g. first hour is $1 and the second hour is $2)
- **Time-of-day pricing** (different prices for peak period or rush hour versus off-peak times)

Another on-street parking pricing policy, **dynamic curbside parking pricing**, is an approach that uses market forces to regularly adapt prices to balance supply and demand. A key benefit is that the price of parking is flexible and responsive to varying parking demand. Analyzing dynamic pricing was considered out of scope of this study as it requires a different analytical methodology and model to account for changing parking prices and demand.

1.2 Study boundary

The study boundary for the econometric and traffic model is the same area as Toronto's Curbside Management Strategy, shown in Figure 1. The study used 54 metered curbside parking zones within the boundary.

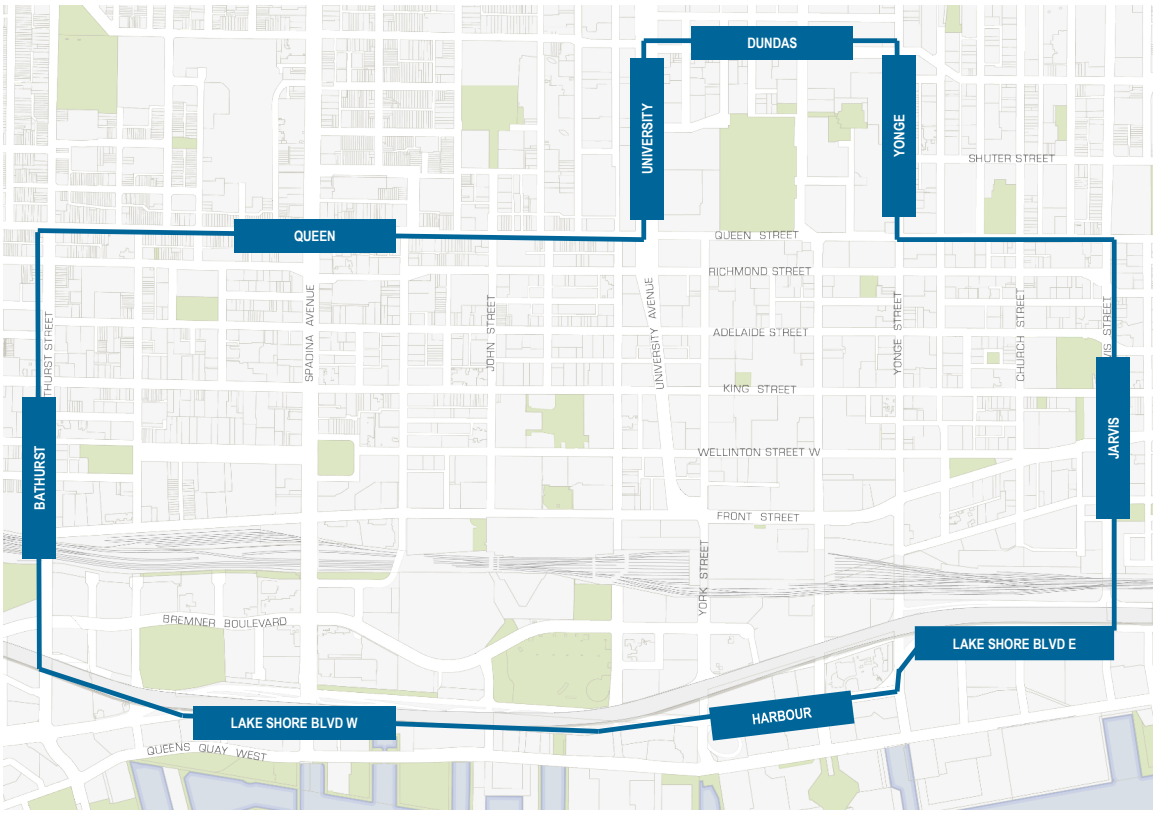

Figure 1. Study boundary

Source: "Curbside Management Strategy"[3]

[3] Barbara Gray, "Curbside Management Strategy," presentation to Public Works and Infrastructure Committee, November 29, 2017, 3. http://www.toronto.ca/legdocs/mmis/2017/pw/bgrd/backgroundfile-109540.pdf

2. Toronto's Curbside Management Strategy

The City of Toronto's Curbside Management Strategy includes three groups of curbside principles to inform policy direction: mobility matters, safe and reliable access, and communicate value to all. Recognizing that the curbside is a valuable and scarce resource, the Curbside Management Strategy recommends the exploration of variable pricing options in the medium term (three to five years) by the City of Toronto:[4]

> **Tactic: Explore variable pricing options**
>
> This tactic proposes to explore variable pricing options, which can be effective at achieving convenient and frequent curbside availability for parking and delivery activity that supports corridor type and curbside function.
>
> This tactic focuses on the [Curbside Management Strategy] guiding principle 'the curbside is a scarce resource with user fees to be applied where appropriate' and the policy themes of 'value', and 'appropriate street use'.
>
> This tactic is best suited to be implemented on mixed-use access and mixed-use main street corridor types, where the curbside function 'access for business' and 'access for people' is prioritized.

Curbside activities and needs of road users and stakeholders change depending on corridor type and adjacent land use. A key outcome of the CMS is a hierarchy of curbside functions by corridor type, illustrated in Figure 2. This helps us to understand on which streets curbside parking is prioritized and where it is of lower importance. Streets that provide access to commercial (retail and office) and residential properties are considered "access matters" corridor types. "Mixed-use access" and "mixed-use main street" are those where curbside parking pricing is especially important to promote the intended curbside function — access for businesses and people. For "mobility matters" corridor types that have a primary purpose to move high volumes of vehicles and support transit and cycling, curbside parking is deprioritized. This study focuses on curbside pricing on streets that are intended to serve the access and parking functions.

[4] *Curbside Management Strategy: Final report*, "Recommended Policy Approach," Section 7.3.2.

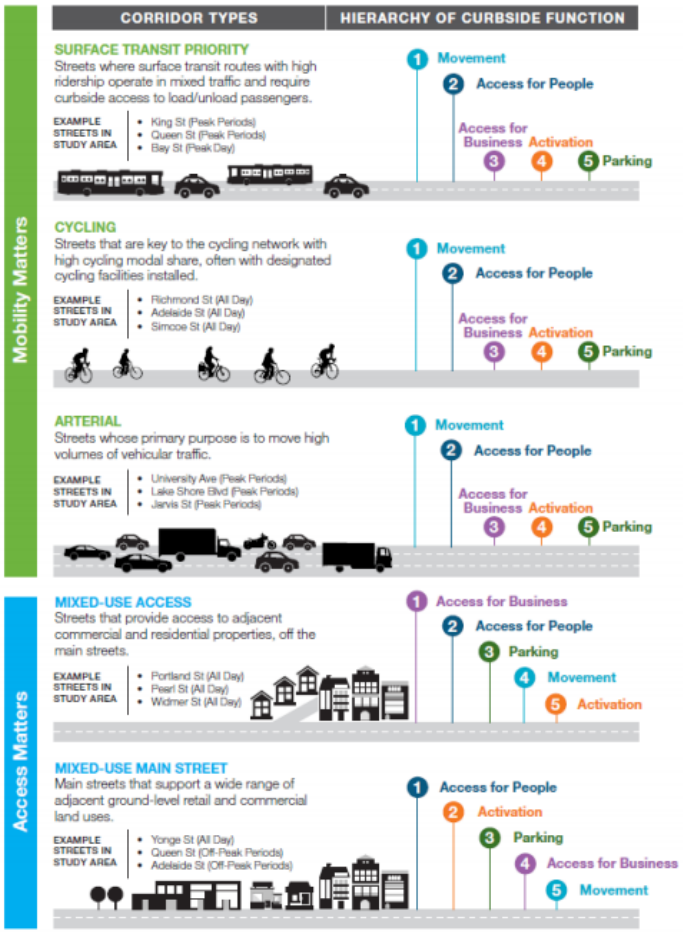

Figure 2. Hierarchy of curbside function by street type

Source: City of Toronto[5]

The CMS acknowledges that the successful implementation of variable curbside pricing requires data on parking supply, demand, and prices. It also depends on a mechanism to pay for parking, additional signage, updated regulations, an education campaign for users, and possibly new parking meters. One of the challenges will be trade-offs with service levels versus system costs (e.g. a curbside policy like dynamic pricing offers benefits and a higher level of parking demand management, but requires a higher upfront investment price), and ability of the Toronto Parking Authority — as operator of all 19,000 metered on-street parking spaces in Toronto — to implement curbside pricing *without* council approval.[6]

[5] *Curbside Management Strategy: Final report,* "Strategy Development and Evaluation," Exhibit 7.

[6] *Curbside Management Strategy: Final report*, "Recommended Policy Approach," Section 7.3.2.

3. Curbside pricing policies

> "Parking can seem like the most humdrum concern in the world. Even planners, who thrill to things like zoning and floor-area ratios, find it unglamorous. **But parking influences the way cities look, and how people travel around them, more powerfully than almost anything else**. Many cities try to make themselves more appealing by building cycle paths and tram lines or by erecting swaggering buildings by famous architects. If they do not also change their parking policies, such efforts amount to little more than window-dressing. There is a one-word answer to why the streets of Los Angeles look so different from those of London, and why neither city resembles Tokyo: parking."
>
> — *The Economist*[7]

In cities across North America, parking has often been unpriced or underpriced. That has exacerbated many urban issues from traffic congestion to carbon emissions and urban sprawl.[8] [9] There is a growing body of academic and grey literature influencing and supporting the trend toward more curbside parking pricing in urban areas of high parking demand. New curbside pricing models, supported by new parking data collection and processing technology, are emerging to better manage curbside parking, to control the demand, and to efficiently allocate this scarce urban resource.

3.1 The rationale for pricing the curb

Curbside parking pricing is an urban transport policy tool for managing the high demand for parking spaces — a common challenge faced by cities around the world. Parking pricing is defined as directly charging for use of a parking space, which may be

[7] "How not to create traffic jams, pollution and urban sprawl," *The Economist*, April 8, 2017. https://www.economist.com/briefing/2017/04/08/how-not-to-create-traffic-jams-pollution-and-urban-sprawl

[8] "How not to create traffic jams, pollution and urban sprawl."

[9] Nagwa Khordagui, "Parking prices and the decision to drive to work: evidence from California," *Transportation Research Part A: Policy and Practice*, 130 (2019). https://doi.org/10.1016/j.tra.2019.09.064

curbside or off-street.[10] According to the United States Department of Transportation, parking pricing has multiple benefits:[11]

- It can allocate the limited resource (finite parking supply) to maximize efficiency of the whole mobility system.
- It reduces market-distorting subsidies that have "induced excess auto travel".
- It generates revenue that can fund mobility and accessibility improvements, thereby reducing the original parking demand.

An advanced curbside parking strategy can help to address peak period parking, more evenly distribute the demand on the streets, and meet parking policy objectives. The need for parking infrastructure, like the need for traffic and other urban infrastructure, increases and decreases throughout the day and across the geography of the city. To maintain balance in the parking system, sophisticated tools are needed to handle the peak demands.

Various pricing strategies and tactics exist, but detailed and documented research on the impact of the different strategies and their average costs and benefits is limited.[12]

Conducting a comparative analysis of curbside pricing policies, especially quantitative impacts, is not easy due to several reasons, such as the diversity of key performance indicators and reporting that is available from various cities. Furthermore, a comparative analysis is difficult because of very different urban contexts, transport modal options, and travel behaviours that all influence the demand for parking. That is why similar parking strategies are often implemented differently in each city; for example, with time restrictions based on local traffic patterns, or differing hourly rates or parking enforcement budgets and operations.

Having said this, our literature review and jurisdictional scan of curbside parking pricing policies has identified overarching concepts behind the pricing of parking:

[10] Todd Litman, *Parking pricing implementation guidelines* (Victoria Transport Policy Institute, 2021). https://www.vtpi.org/parkpricing.pdf

[11] Matthew Kaufman, Matthew Formanack, Joddie Gray, Rachel Weinberger, *Contemporary approaches to parking pricing: a primer* (Federal Highway Administration, U.S. Department of Transportation, 2012). https://ops.fhwa.dot.gov/publications/fhwahop12026/fhwahop12026.pdf

[12] Zhenyu Mei, Chi Feng, Liang Kong, Lihui Zhang, and Jun Chen, "Assessment of Different Parking Pricing Strategies: A Simulation-based Analysis," *Sustainability*, 12 (2020), 2056. https://doi.org/10.3390/su12052056

- **Parking pricing rates influence driver behaviour**.[13] [14] Presented with a higher curbside parking rate than anticipated, a driver may choose to change precise parking location or change mode of transport the next time they travel to the area. A strategic pricing scheme and appropriate rate structure can more evenly distribute the parking demand in busy urban areas.
- **Many drivers are willing to pay more to reduce walking time to destination**.[15] Everyone values time differently. Many drivers are willing to pay more to achieve benefits like reduced walking distance and time to the ultimate destination, and reduced searching time to find parking. This concept underpins the notion of variable parking pricing on different street blocks in response to local parking demand.

The following section describes pricing policies, pros and cons, and policy considerations of each, and highlights cities that are actively implementing pricing policies.

3.2 Hourly pricing

Description

In hourly curbside pricing, drivers are charged by the hour for on-street parking ; rates generally do not change throughout the day (although there may be some exceptions, such as free night-time parking). The rates may vary across the city depending on parking demand, which is a response to the various land uses and densities of urban development.[16] Hourly curbside pricing is the existing pricing policy in Toronto; rates are $1 to $5 per hour.

Advantages

An advantage of hourly pricing is that it is generally easy to implement for the municipality and it is easy for users to understand a simple, constant, hourly rate. No

[13] Richard Wilson, "Estimating the travel and parking demand effects of employer-paid parking," *Regional Science and Urban Economics,* 22 no. 1 (1992), 133-145. https://doi.org/10.1016/0166-0462(92)90029-Z

[14] Dimitrios Tsamboulas, "Parking fare thresholds: a policy tool," *Transport Policy*, 8 no. 2 (2001), 115-124. https://doi.org/10.1016/S0967-070X(00)00040-8

[15] Rong Zhang and Lichao Zhu, "Curbside parking pricing in a city centre using a threshold," *Transport Policy*, 52 November (2016) 16-27. https://doi.org/10.1016/j.tranpol.2016.06.008

[16] *Contemporary approaches to parking pricing.*

special equipment is required beyond single- or multi-space parking meters (with or without electronic payment/pay-by-phone), and it uses regular signage outlining the hourly rates.

Disadvantages

First, hourly pricing may not adequately manage parking demand as it does not respond to the temporal differences in parking demand throughout the day that are dictated by the adjacent land uses. This sometimes causes dissatisfied users who are unable to find a space to park at peak hours. It also creates added traffic congestion when drivers cruise for parking, as well as possible double-parking and unsafe vehicle maneuvering, and increased emissions from the cruising.

Second, on city blocks where higher parking turnover is needed, there may be insufficient incentive to encourage short-stay/high-turnover parking, unless parking time limitations are well-enforced. Short-stay/high-turnover curbside parking is advantageous where adjacent land uses include retail, restaurants, and commercial services such as banks, etc. If users assess the hourly price to be adequately low to park all day, they may do so unless time limitations prevent such practices (other pricing strategies solve this issue). The implications for businesses and the economy of pricing policies that encourage higher curbside turnover are further discussed in the dynamic pricing section.

Application

Hourly pricing is the existing curbside parking strategy in many Canadian municipalities, including the City of Toronto, the City of Montreal, and the City of Edmonton.[17] [18] [19] In the case of Toronto, this parking policy is failing to effectively manage high demand curbside parking on some streets in the downtown core (Figure 3):

- Some areas (shown in red) are overutilized (80-100% occupancy) and become challenging streets on which to find curbside parking during peak hours.

[17] City of Toronto, "Toronto Parking Authority (TPA) – parking meters – malfunctioning parking meters – graffiti." https://www.toronto.ca/311/knowledgebase/kb/docs/articles/special-purpose-bodies-and-external-organizations/toronto-parking-authority/toronto-parking-authority-tpa-parking-meters-malfunctioning-parking-meters-graffiti.html

[18] Agence Mobilite Durable (Montreal), "Paid on-street parking." https://www.agencemobilitedurable.ca/en/fees.html

[19] City of Edmonton, "Parking rates, hours and locations." https://www.edmonton.ca/transportation/driving_carpooling/rates-hours-locations.aspx

- Many areas are underutilized (shown in yellow), even though they are geographically close to the overutilized areas shown in red.

This inconsistent curbside parking demand distribution would likely be improved with a change in parking pricing policy — progressive hourly, time-of-day, or dynamic pricing.

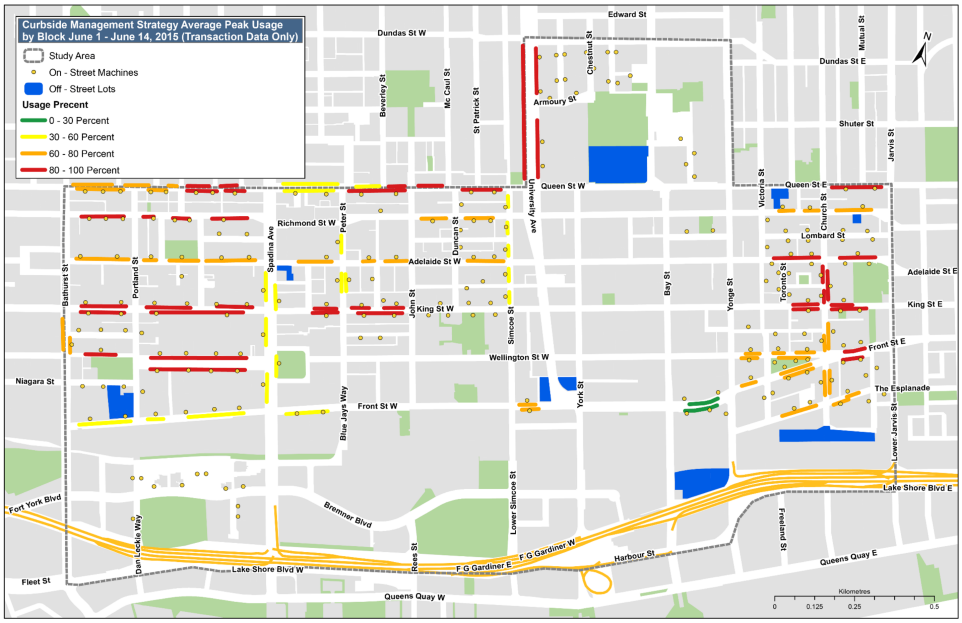

Figure 3. Average peak occupancy by block in downtown Toronto

Source: City of Toronto[20]

Similarly, in the United States, the City of Chicago uses hourly pricing for curbside parking.[21] Rates are charged by zone in Chicago, with the highest hourly rate in the central business district (2021 rates):[22]

- $2.25 per hour: Non-downtown areas
- $4.50 per hour: Downtown, non-central business district
- $7.00 per hour: Downtown, central business district

Unlike many other cities, Chicago has contracted out operations of the approximately 35,000 metered curbside parking spaces for 75 years to Morgan Stanley in exchange for

[20] *Curbside Management Strategy: Final report,* "Existing Conditions Review," Exhibit 3.20.

[21] Inter-American Development Bank, *Practical guidebook parking and travel demand management policies in Latin America*, (2013). https://publications.iadb.org/publications/english/document/Practical-Guidebook-Parking-and-Travel-Demand-Management-Policies-in-Latin-America.pdf

[22] Park Chicago, "Chicago street parking changes to take effect in 2021." https://parkchicago.com/chicago-street-parking-changes-to-take-effect-in-2021/

a one-time payment of US$1.157 billion.[23] The city, however, retains control over the hourly rates charged.[24]

3.3 Progressive hourly pricing

Description

Progressive hourly pricing, also known as escalating rates, is another curbside pricing option. The price per hour is lower for the first hour that a car is parked, and then rises with each subsequent hour.[25] Individual rates vary by geography in the city to manage demand in response to local uses and densities. The rate structure typically applies all day and does not vary in response to daily temporal demand fluctuations (but could if paired with other parking policies).

Smart parking meters, with or without mobile phone payment options, are needed to facilitate the varying pricing structure of a progressive hourly curbside pricing policy.[26] Smart parking meters allow a person to choose to make one payment transaction for their needed parking duration at the stated price, or to pay the meter at multiple points throughout the parking duration if they so choose (if parking regulations allow). The second option allows use of the lower parking rates, but forces the inconvenience of multiple, frequent payments. Smart meters also allow the use of credit and debit cards, as well as tap transactions.[27]

Advantages

A large advantage of progressive hourly parking policy is that time limits can be eliminated because long-stay parking is managed through pricing. Parking for longer durations costs more than in a simple, hourly parking policy environment since rates increase with the amount of time parked. This creates a similar effect to time

[23] *Practical guidebook parking and travel demand management policies in Latin America.*

[24] "Chicago street parking changes to take effect in 2021."

[25] *Contemporary approaches to parking pricing.*

[26] More and more people are using mobile options to pay for curbside parking. The decision to forego parking meters and focus on mobile applications may be a consideration in the future, but would likely always involve a social equity element as it would exclude people without a mobile phone.

[27] Michael Klein, "Progressive parking prices," in *Parking and the City,* ed. Donald Shoup (New York: Routledge, 2018), 283.

limitations.[28] Thus, the risk of long stays and low turnover in, for example, main streets and retail areas, is managed while allowing some flexibility for those who wish to park longer and pay for it. This sophistication accommodates multiple types of users, but manages the finite public resource — making better use of public urban real estate. Further, more revenue can be generated in progressive hourly parking than in hourly pricing because of the lack of time limits and the structure of increasing rates per hour.

Disadvantages

Progressive hourly pricing introduces some complexity because hourly rates vary according to parking duration, but any possible confusion on the part of drivers can be mitigated with clear instructions at meters and in mobile payment applications.[29] Further, clear signage on-street and a public communications campaign at rollout to educate the community can reduce any misunderstandings about the policy, the purpose, and the use of extra revenue generated. It can be made clear that this is a transport policy tool, not a general-purpose revenue-generating tool.

Other policy considerations

Policy practitioners should consider how this parking strategy disproportionately impacts drivers with lower incomes or persons with disabilities. Though its impacts are unlikely to be major since lower-cost parking is typically available a few blocks away, and accessible parking can be accommodated in different ways, the escalating rate may negatively affect some people.[30]

Application

Albany, New York, Aspen, Colorado, and some districts in New York City are examples of places that have implemented progressive hourly curbside parking pricing policy.[31] Prior to the progressive pricing policy in Albany, the city had two-hour parking-time limitations and simple, hourly pricing. Now, with the new progressive pricing, the first two hours are priced at US$1.25 per hour, and each subsequent hour costs an additional $0.25 per hour added cumulatively (e.g. hour 1 costs $1.25, hour 2 is $1.25, hour 3 is $1.50, hour 4 is $1.75, etc.).

---

[28] "Progressive parking prices."

[29] *Contemporary approaches to parking pricing*, 32.

[30] *Parking pricing implementation guidelines*, 14.

[31] "Progressive parking prices."

> "Progressive parking prices in Albany have reduced parkers' anxiety by providing customers with a simple solution to the on-street parking challenge. Customers no longer worry about the old two-hour time limits, parking generates more revenue, and curb space is better managed with market forces."
>
> — Mayor of Albany, New York[32]

Post-implementation key performance metrics of the progressive parking policy are summarized in Table 1. Of particular interest in this table is the percentage of people parking longer than the previous two-hour time limit: nearly a quarter of all people chose to pay the higher rates and used more than two hours, generating a large amount — 59% — of the revenue collected from on-street parking. Clearly, there was latent demand for this longer-term parking in Albany, and people were willing to pay for it.

Table 1. Results of the implementation of progressive hourly pricing in Albany, NY

Key performance indicator	Measurement
Average duration	115 minutes
Turnover	3.5 vehicles/space/day
Paid occupancy	63%
Percent parking longer than two hours (old time limit)	22%
Revenue generated from long-stay (longer than 2 hours) as % of total	59%

Data source: Klein[33]

Another example of a jurisdiction with progressive hourly pricing is Aspen, Colorado. Aspen has a large differential in its progressive parking prices to help manage the high parking demand created by summer tourism: US$1.00 for the first 30 minutes, $3 for the first hour, $7.50 for the second hour, $13.50 for the third hour, and $21.00 for the fourth hour. New York City also has progressive parking pricing in some areas.[34]

[32] Quoted in "Progressive parking prices."

[33] "Progressive parking prices."

[34] *Contemporary approaches to parking pricing.*

Looking to Europe, Antwerp, Belgium, also has progressive parking pricing.[35] Antwerp uses a public–private partnership to run curbside parking and public off-street lots. The nature of a public–private partnership encourages innovation in curbside parking including measures like new data collection and enforcement technologies. It allows flexibility in employee work agreements and supports charging the highest reasonable parking prices — though these still must be approved by city council.

Antwerp curbside parking pricing rates are structured by zone: Zone 1: Central Station and central business district; Zone 2: within the single semi-ring-road zone; and Zone 3: outside the single semi-ring-road zone. Rates and maximum parking durations in these zones are:

- Zone 1 (3-hour max.): €1.50 first hour, €2.50 second hour, €3.50 third hour
- Zone 2 (10-hour max.): €0.60 first hour, €1.00 subsequent hours
- Zone 3 (10-hour max.): €0.50 per hour

3.4 Time-of-day pricing

Description

Time-of-day pricing, also known as variable rates in time, sets parking prices that change throughout the day based on parking demand. Prices could also vary throughout the week as weekdays and weekends often have different parking demand profiles.[36] Similar to other pricing policies, individual rates often vary throughout the city to manage demand in response to local uses and densities.

Time-of-day curbside parking pricing has proven to be an effective strategy to shift demand from congested times and areas to uncongested times and areas.[37]

Advantages

Time-of-day pricing has an advantage in that cities can charge lower rates during off-peak times and higher, market rates during peak times that are more in line with pricing

[35] Michael Kodransky and Gabriella Hermann, *Europe's parking u-turn: from accommodation to regulation*, (Institute for Transportation and Development Policy, 2011). https://itdpdotorg.wpengine.com/wp-content/uploads/2014/07/Europes_Parking_U-Turn_ITDP.pdf

[36] *Contemporary approaches to parking pricing.*

[37] *Parking pricing implementation guidelines*, 14.

at off-street parkades.[38] This has benefits for people who seek lower cost parking and are willing and able to travel during off-peak times to obtain it. Further, market rates at peak times can encourage off-peak travel as a form of travel-demand management as some people will time their trips to take advantage of cheaper parking. Parking pricing is cited as the second-most-effective congestion reduction mechanism after peak congestion fees; it can be more effective than vehicle miles travelled (VMT) fees, fuel taxes, and emission fees.[39]

Disadvantages

Like progressive hourly parking, time-of-day pricing introduces some complexity for drivers as the varying hourly rates depend on whether they are parking during peak periods or not. However, any possible confusion by drivers can be mitigated with clear communications of rates and instructions at meters and in mobile payment applications.

Application

New York City has implemented time-of-day pricing in several areas, and the peak pricing periods are different in various neighbourhoods depending on parking demand.[40] One neighbourhood, for instance, has peak pricing between noon and 7 p.m., while another has peak pricing between 6 p.m. and 10 p.m.

3.5 Dynamic pricing

Description

Dynamic curbside parking pricing is an on-street parking pricing approach that uses market forces to frequently adapt prices to balance supply and demand. Though one of the more expensive policies to implement due to the data collection instruments and frequent analysis required, dynamic pricing offers benefits to the municipality and the users. It is the only curbside pricing strategy that fluctuates in accordance with current

[38] Meghan Mitman, Steve Davis, Ingrid Ballus Armet, and Evan Knopf, *Curbside management practitioners guide* (Institute of Transportation Engineers). https://www.ite.org/pub/?id=C75A6B8B-E210-5EB3-F4A6-A2FDDA8AE4AA

[39] *Parking pricing implementation guidelines*, 14.

[40] *Contemporary approaches to parking pricing.*

parking demand in popular main street areas or nodes with a mix of uses like restaurants, businesses, etc.

This study did not evaluate the potential impacts of dynamic pricing in Toronto given the further analytical methods needed to assess dynamic pricing in addition to the method of the other three parking pricing policies. An evaluation of dynamic pricing in Toronto would require the development of a different modelling methodology to account for the frequently changing parking prices in response to the observed curbside demand.

Advantages

Dynamic pricing has the distinct advantage of being able to treat curbside parking like a free market and manage it accordingly. As such, dynamic pricing offers:[41]

- Price flexibility
- Improved availability and ease to find parking
- Even spatial distribution of parking demand
- Economic vitality (sales tax revenue growth and general business support through better managed parking)
- Reduced vehicle miles travelled and GHGs
- Reduced congestion
- Reduced double-parking
- Improved transit speeds due to reduced congestion and double-parking

Disadvantages

As described above, dynamic pricing is one of the more expensive curbside pricing policies to implement. Dynamic pricing requires:

- Collecting, storing, and interpreting a significant amount of data to repeatedly set the prices on each street block.
- Investment, both upfront and ongoing, to acquire and manage data collection equipment.

Application

One of the earliest adopters of dynamic pricing in North America is the City of San Francisco, California. The city used in-street wireless sensors to collect and send parking occupancy data to the municipal authority to enable close monitoring and price

[41] Jay Primus, "SFpark," in *Parking and the City*, 322.

changes, which occurred about every eight weeks over a two-year period, to try to achieve the target range of occupancy of 60-80% (the rates above which people often feel parking is difficult to find). When occupancy was higher than 80%, the price was raised by US$0.25 per hour. When occupancy was between 30% and 60%, the price was lowered by $0.25 per hour. When it was lower than 30%, the price was lowered by $0.50 per hour. A price floor of $0.25 per hour and ceiling of $6 per hour were set by the authority, and prices were never raised by more than $0.25 per hour in a rate change. This dynamic pricing strategy was piloted between 2011 and 2013 with an extensive data collection and monitoring program as well as a control area to compare results. It yielded many positive elements.

Average curbside hourly rate price drop and spatial distribution

Throughout the San Francisco dynamic pricing pilot, prices went up on half of the blocks in the pilot area and down on the other half but, overall, they dropped by 4%, as shown in Figure 4.

Figure 4. Average San Francisco curbside prices per hour

Data source: Primus[42]

One surprising result of the dynamic pricing pilot project was the spatial distribution of parking demand and resulting prices:

> "The geographic distribution of prices was also unexpected, with some $0.25 per hour parking spaces literally around the corner from much more expensive parking. This reinforces the lesson that it is likely impossible to predict the "right" price for parking for

[42] "SFpark," 322.

any given time and place. Empirically adjusting prices in response to observed demand is a better approach, yielding superior outcomes."[43]

The spread of hourly rates following the introduction of dynamic pricing is listed in Table 2. It shows a large distribution of hourly rates; at the outset 40.5% of meters were at US$2/h, 29.3% were at $3/h, and 30.2% were at $3.5/h. At the end of the dynamic parking pilot (interval #10), there were parking meters operating in every price interval of $0.25 from the price floor of $0.25/h to the price ceiling of $6/h. Further, 16.5% of total operating hours at the end of the pilot were charged at the low rate of $0.25/h.

This spread of hourly rates is worth noting. Clearly the optimization of curbside parking supply and demand involves many different hourly rates across the geographic area — and fluctuating rates in response to regular market changes.

[43] "SFpark," 331.

Table 2. Spread of hourly rates before/after dynamic pricing was introduced

Rate ($/h)	Share of operating hours at each price (%)						
	Initial rates	Regular price adjustment intervals in dynamic pricing pilot					
		#1	#2	#3	#4	[…]	#10
$0.25					0.0		16.4
$0.50					0.4		4.3
$0.75				0.2	0.3		2.7
$1.00				0.3	3.4		3.8
$1.25			0.2	3.8	2.8		3.2
$1.50		0.0	4.7	4.0	4.0		4.5
$1.75		5.6	6.1	5.6	7.0		5.4
$2.00	40.5	20.1	14.5	14.5	16.2		6.7
$2.25		14.8	8.6	13.1	9.0		4.0
$2.50		2.2	21.3	8.5	10.1		5.1
$2.75		12.8	6.7	18.1	6.6		3.1
$3.00	29.3	11.9	11.0	6.3	14.2		4.5
$3.25		13.9	6.6	5.0	4.7		4.7
$3.50	30.2	13.1	13.4	10.1	9.4		6.0
$3.75		5.7	2.8	5.0	4.0		5.2
$4.00			4.1	2.2	3.9		4.8
$4.25				3.3	1.4		4.3
$4.50					2.6		4.7
$4.75							1.3
$5.00							1.4
$5.25							1.1
$5.50							1.7
$5.75							0.5
$6.00							0.6
Total percent	100	100	100	100	100		100

Data source: Primus[44]

[44] "SFpark," 322.

Occupancy and reported time to find parking

The pilot program in San Francisco reduced the percentage of time that curbside parking was near full occupancy (defined as between 90-100% occupied) over the course of a day, as shown in Figure 5. This also resulted in 43% less time reported to find available parking.

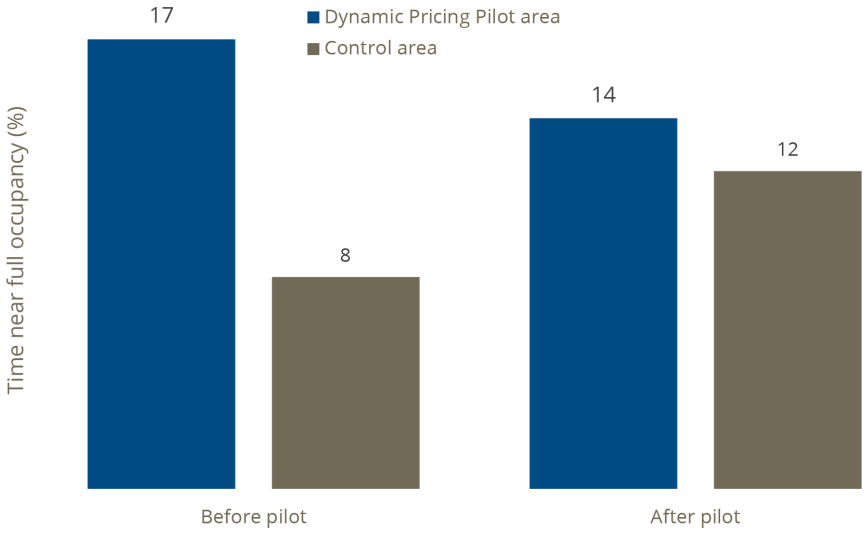

Figure 5. More curbside parking availability because of dynamic pricing

Data source: Primus[45]

Vehicle miles travelled and greenhouse gas emissions reduction

Further to the above results, vehicle miles travelled and greenhouse gas emissions also went down during the dynamic pricing parking pilot project. Specifically, 30% fewer vehicle miles were recorded in the pilot area of San Francisco and less GHGs were emitted as a result.

Sales tax revenue increase, and economic vitality

The dynamic parking pilot facilitated parking for choice trips like shopping and dining, and likely resulted in a shift to non-driving modes of transport for people travelling for work or school. Further, the sales tax revenue in the pilot area grew faster than in other areas of the city. These two points combine to suggest that dynamic pricing has helped the local economy of San Francisco.

[45] "SFpark," 322.

> "The share of people visiting pilot or control areas for shopping, dining, or entertainment did not change over the course of the pilot project. Of those who drove to the pilot areas, however, there was a 30% increase in people who visited to shop or dine compared to people who drove for other reasons, such as work or school."[46]

Negative economic impacts are often cited as a reason to avoid making changes to the structure of parking prices, and especially to avoid raising prices. However, as seen in San Francisco, the whole urban mobility system can be better managed with dynamic curbside parking pricing.

[46] "SFpark," 339.

4. Curbside pricing modelling

4.1 Methodology

This section documents the modelling process that was developed and performed by York University to analyze the curbside pricing policy options. The process involves four steps (Figure 6).

1. Data analysis: Gather traffic and parking data and process it for modelling.
2. Econometrics and optimization modelling: Estimate parking behaviour mathematically, generate the optimal parking prices for the progressive hourly policy, and estimate parking dwell times (parking durations).
3. Simulation modelling: Simulate operation of the downtown street network under the pricing policies in two scenarios: peak and off-peak.
4. Parking pricing scenario analysis: Compare the impacts — assessed from the simulation modelling — of the different parking pricing policies on the established measures of effectiveness.

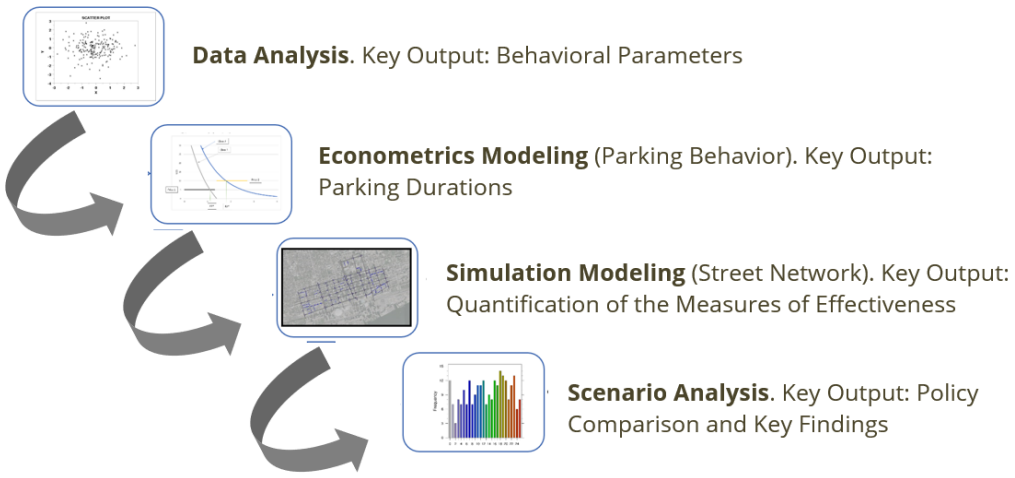

Figure 6. Analysis and modelling process

Source: York University, modified by the Pembina Institute[47]

[47] David Ornelas, Mehdi Nourinejad, Peter Park, and Matthew J. Roorda. *Pricing options as a curbside management tactic for the City of Toronto.* York University and the Smart Freight Centre. August 25, 2021.

Modelling steps

1. Data analysis

Data sources provided by the City of Toronto and the Toronto Parking Authority were used to characterize the current state of parking within the area boundaries of the Curbside Management Strategy of downtown Toronto. This step included the following tasks:

- Used existing parking pricing and on-street parking occupancy data to characterize parking behaviour.
- Used intersection counts data to generate traffic flows on the downtown street network.

2. Econometric (behavioural) modelling and optimization

The econometric modelling was completed to develop a mathematical understanding of parking behaviour. This modelling was also used to estimate optimal parking prices for the progressive hourly pricing policy that maximize social welfare — defined as the sum of city parking revenue and user benefit (user benefit: parking is available and people can use it). This step included the following tasks:

- Used parking pricing and occupancy data to estimate a marginal utility function of parkers.
- Derived the optimal parking prices in the progressive hourly pricing policy for two user classes: passenger and commercial vehicles. The progressive hourly price includes two decisions of the nominal price: the escalated (augmented) price for the second time increment, and the cut-off time between prices. This model assumes commercial vehicle users would be typically willing to pay more. The time-price relationship of these two users are shown in Figure 7.
- Used the existing prices in Toronto for the hourly pricing policy.
- Used the existing prices for peak period, and 50% of the existing prices for the off-peak period to determine the time-of-day pricing.
- Generated parking dwell times (durations) distributions to be used in the simulation modelling.
- Evaluated the optimal progressive hourly parking pricing designs to maximize social welfare (defined above). This is summarized in Figure 8.

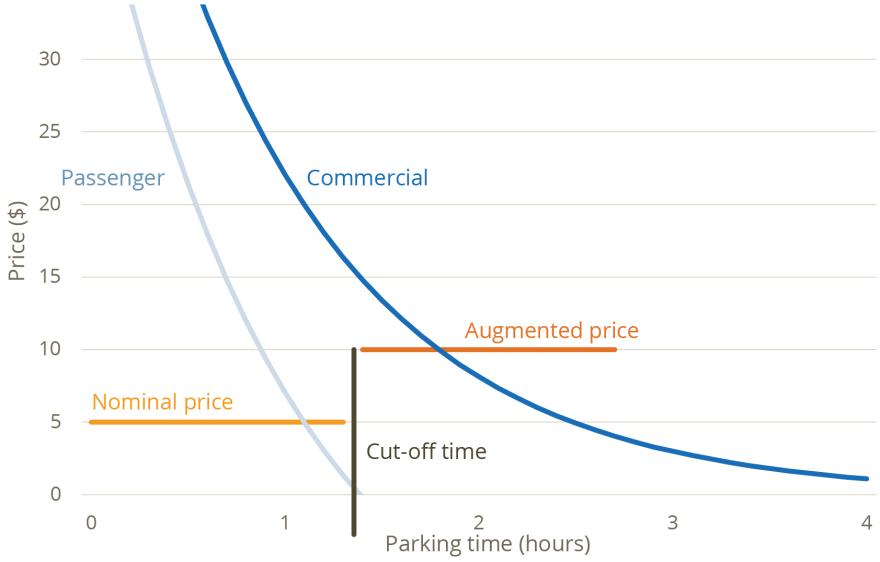

Figure 7. Progressive hourly pricing time-price curve for passenger and commercial vehicles

Source: York University, modified by the Pembina Institute[48]

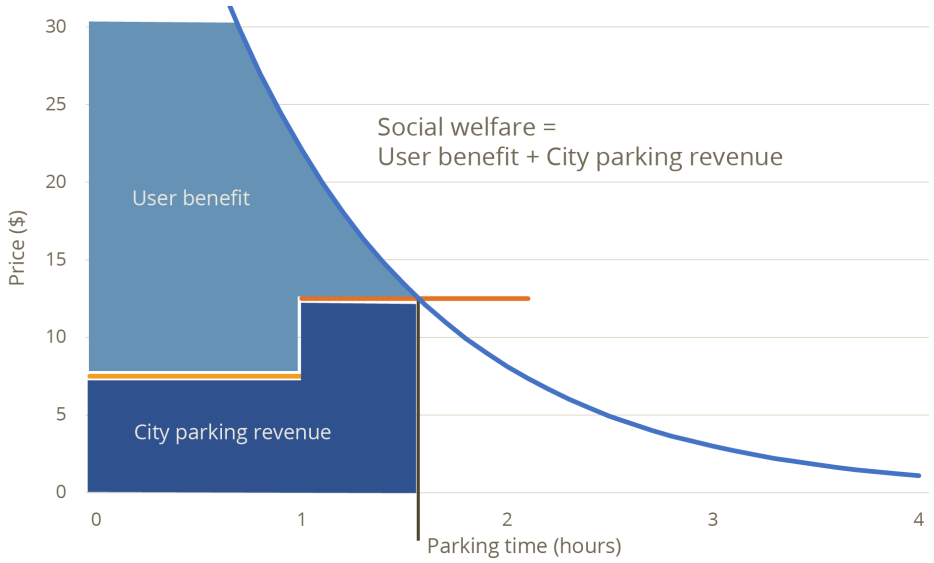

Figure 8. Relationship between city parking revenue, user benefit, and social welfare

Source: York University, modified by the Pembina Institute[49]

[48] David Ornelas, Mehdi Nourinejad. *Methodology overview.* York University and the Smart Freight Centre. December 2020.

[49] *Methodology overview.*

3. Simulation modelling (street network)

A simulation modelling exercise was completed to understand the operation of the street network under the different parking pricing policies, using the outputs generated in the econometric modelling step. Key tasks included:

- Built a simulation network of Toronto in Vissim software.
- Modelled the parking supply and simulated the parking behaviour of travellers in downtown Toronto.

4. Scenario analysis

Scenario analysis was the final step in the process and involved summarizing the impacts quantified in the simulation model and comparing the pricing policies and peak and off-peak scenarios. This step included the following tasks:

- Performed sensitivity analysis.
- Compared the three pricing policies on the established measures of effectiveness, including:
  - Parking space occupancy
  - Cruising time (driving around and trying to find a parking space)
  - CO_2 emissions
  - Total network travel time
  - Revenue generation from parking fees (not infractions)

4.1.1 Additional note on the derivation of parking prices in progressive hourly

To derive the optimal parking prices in the progressive hourly pricing policy, several steps were used:

- A pricing profile was developed which included a changing, stepwise structure. The price per hour that drivers pay is p_1 if they park less than q hours, and the price per hour drivers pay for every additional hour parked beyond q hours is p_2.
- This pricing profile was used to investigate the reactive behaviour of the drivers in the econometric modelling. Some drivers choose to shorten their parking dwell time if price p_2 is too large and they have the ability to do so.
- Two metrics were generated from the reactive behaviour of the drivers: revenue and social welfare. Revenue is the sum of the parking price that drivers pay and social welfare is the sum of the revenue and the benefit gained by drivers from parking (as they engage in socially or economically beneficial activities while parking).

- The pricing profile was adjusted and tested several times to generate the optimal prices that maximize revenue and social welfare.
- This process was repeated for each of the 54 on-street parking zones in the study area.

4.2 Key model inputs

Table 3 describes the inputs that were used in the model.

Table 3. Key model inputs

Input	Description
Traffic volumes	Peak period volumes September 2019, 23 intersections in the Curbside Management Study area, (pre-pandemic data; source: City of Toronto)
Parking demand	Parking payment transactions September 2019 in 54 curbside zones (source: Toronto Parking Authority)
Parking prices	
Hourly pricing	Existing hourly prices in the 54 zones (source: Toronto Parking Authority): 10 zones at $3/hour 20 zones at $4/hour 24 zones at $5/hour
Progressive hourly pricing	Existing parking demand data from the Toronto Parking Authority (what people are willing to pay for curbside parking in downtown Toronto): See reference to report with list of modelled prices in each zone.[50]
Time-of-day pricing	Peak period: same prices as hourly prices Off-peak period: 50% of the hourly prices

[50] David Ornelas, Mehdi Nourinejad, Peter Park, and Matthew J. Roorda. *Pricing options as a curbside management tactic for the City of Toronto.* York University and the Smart Freight Centre. August 25, 2021.

4.3 Pricing policy evaluation framework

To evaluate and understand the different pricing policies investigated in this study, an evaluation framework was developed that considers policy effectiveness, geographic scale (street block level and entire study area), and time (Table 4). The measures of effectiveness at the street block level were average parking occupancy, parking revenue, and average cruising for parking. The measures of effectiveness investigated over the entire study area were network travel time and greenhouse gas emissions.

Table 4. Pricing policy evaluation framework: measures of effectiveness

Measures of effectiveness	Scale	Units	Description
Parking occupancy	Street Block	%	A weighted average of the many on-street parking zones in the study area was used to generate one parking occupancy percentage per pricing policy. The weighted average was completed using the number of parking spaces in a zone relative to the total number of parking spaces in the study area.
Parking revenue	Street Block	$ per hour	Based on parking occupancy and the pricing rates.
Cruising for parking	Street Block	%	The ratio of people unable to park over the total demand to park in the zone. Cruising for parking is also a weighted average, calculated in the same manner as described in parking occupancy above.
Network travel time	Study Area-Wide	Hours	The total network travel time of all vehicles in the network occurring in the one-hour analysis period (morning peak hour in the peak scenario and an off-peak hour in the off-peak scenario).
GHG emissions	Study Area-Wide	kg of CO_2e per hour	Calculated using literature-established emissions factors with network modelling outputs.

Furthermore, to understand the interaction between parking demand, price, and traffic volumes, the model analyzed two time periods: peak period and off-peak.

Peak period: Period of highest traffic volumes. In this time period, hourly and progressive hourly pricing options were analyzed; time-of-day pricing is the same as hourly pricing in the peak period.

Off-peak period: Periods of lower traffic volumes (assumed to be reduced by 50% compared to peak traffic conditions). Hourly, progressive hourly, and time-of-day pricing options were analyzed. In the off-peak period, time-of-day prices are 50% of the hourly prices.

5. Results

5.1 Outcomes in the measures of effectiveness

Results were obtained in the five measures of effectiveness under the two separate modelling scenarios of peak and off-peak periods: parking occupancy, parking revenue, cruising for parking, total network travel time, and greenhouse gas emissions. The results of both peak and off-peak scenarios, with all pricing policies, are summarized in Table 5.

Table 5. Results of the three pricing policies, under the two scenarios

Measure of Effectiveness	Pricing Policy					
	Hourly		Progressive hourly		Time-of-day	
	Peak	Off-peak	Peak	Off-peak	Peak	Off-peak
Parking occupancy, high-demand locations (Occupancy >50%) (% of spaces, weighted)	76.64%	67.07%	71.00%	61.59%	N/A	67.31%
Parking occupancy, low-demand locations (Occupancy <50%) (% of spaces, weighted)	24.48%	28.78%	23.99%	27.70%	N/A	30.53%
Parking revenue ($/hour)	$2,522.58	$1,880.55	$5,790.19	$4,617.18	N/A	$873.47
Cruising for parking (% of vehicles unable to find a space, weighted)	32.29%	11.11%	19.81%	6.13%	N/A	11.49%
Total network travel time (hours)	2249.76	1074.55	2224.09	1060.04	N/A	1088.89
GHG emissions (kg CO_2e/h)	6,569	3,572	6,494	3,524	N/A	3,620

5.2 Key learnings and discussion

Parking occupancy

Parking occupancy — an important measure of effectiveness that controls several other measures — was assessed under the three pricing policies in both peak and off-peak scenarios, and different results were observed. However, occupancy changes were noted only in the high-demand parking zones of the study area, defined as greater than 50% occupancy under current pricing conditions.

In the high-demand parking zones, the introduction of a progressive hourly pricing policy reduced the average occupancy by more than five percentage points (from 76.64% occupied to 71.00%, or a 7% reduction) compared with the hourly policy. This result was observed in both the peak and off-peak periods. In the time-of-day pricing modelling (modelled at off-peak only), no significant change in occupancy was seen compared to the hourly pricing policy.

However, in the low-demand parking zones, differing pricing policies showed smaller effects on average occupancy. This is because areas of lower parking demand have lower parking prices. As such, the change from hourly pricing to progressive pricing did not increase the total user cost of parking much in absolute terms (i.e. total dollar amount), which, in turn, did not have a significant impact on driver behaviour.

These results show that introduction of progressive hourly pricing is a more effective way to reduce average parking occupancies than hourly or time-of-day.

Parking occupancies resulting from the introduction of progressive hourly from hourly are shown in Figure 9.

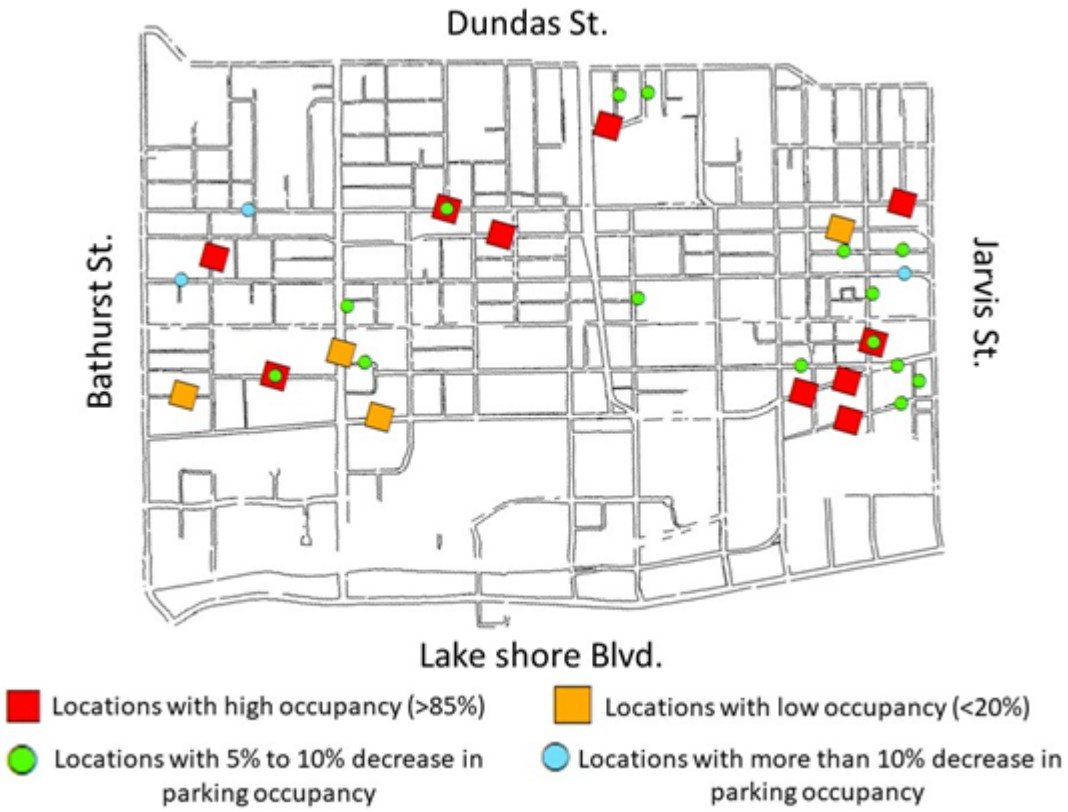

Figure 9. Zones of largest reduction in parking occupancy from introduction of progressive hourly from hourly pricing

Source: York University[51]

Parking revenue

Analysis shows that progressive hourly pricing maximizes parking revenue. Collected parking revenue more than doubled in the peak period, from $2,500 total per hour in all curbside zones with hourly pricing to $5,800 total per hour in all curbside zones with progressive hourly pricing. This results from the higher, optimized rates charged after the first increment of parking duration. A similar result was observed in the off-peak scenario, from $1,900 total per hour with hourly pricing to $4,600 total per hour with progressive hourly pricing.

The time-of-day pricing policy in the off-peak naturally generates less revenue than hourly pricing, with off-peak prices set at 50% of peak prices.

[51] David Ornelas, Mehdi Nourinejad, Peter Park, and Matthew J. Roorda. *Pricing options as a curbside management tactic for the City of Toronto.* York University and the Smart Freight Centre. August 25, 2021.

Cruising for parking

On the measure of cruising for parking, again the introduction of progressive hourly pricing yielded positive results. In the peak period scenario, progressive hourly pricing reduces the number of vehicles that cruise and search for available parking spaces by close to 13 percentage points, or almost 40%, compared to hourly pricing. A smaller reduction was observed in the off-peak scenario. Minimal change was noted in the time-of-day pricing policy, likely due to the minimally changed parking occupancies that were also observed in time-of-day pricing.

Total network travel time and greenhouse gas emissions

A switch to progressive hourly pricing from hourly pricing resulted in a minor decrease in the total network travel time in both peak and off-peak periods. And, as greenhouse gas emissions were calculated with established factors applied to network travel times, a similar result was observed in this measure. Travel time changes and therefore GHG emission reductions were negligible in the time-of-day pricing scenario.

The relationship between occupancy and cruising for parking

As parking occupancy increases, so too does the amount of cruising for parking, shown in Figure 10. Further, the relationship between occupancy and cruising for parking in hourly pricing is stronger than in progressive hourly pricing; more cruising for parking comes from each additional increment of occupancy under hourly pricing, as compared to progressive hourly pricing. In other words, it can be more difficult to find parking with hourly pricing (existing situation). This is clear evidence of the need for a more sophisticated curbside pricing policy to keep curbside occupancies low — to minimize the search for parking and the resulting congestion, emissions, and driver frustration.

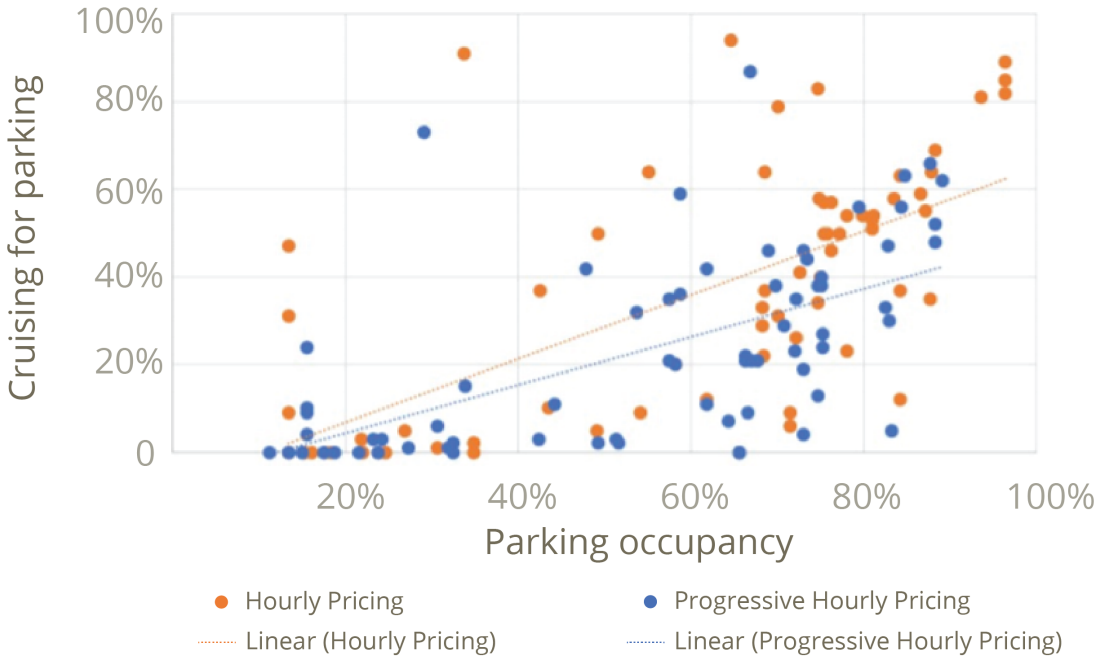

Figure 10. Cruising for parking grows as curbside parking occupancy increases

Source: York University, modified by the Pembina Institute[52]

5.3 Progressive hourly pricing achieves results

Overall, the econometric and traffic modelling analysis shows that a progressive hourly pricing policy in downtown Toronto is an effective approach to manage the challenges that Toronto faces today. Specifically, a progressive hourly pricing policy:

- Keeps curbside parking occupancies lower. In the peak period, progressive hourly pricing reduces the average occupancy rate by **7%** compared with hourly pricing (existing condition). Lower occupancy makes parking easier to find.
- Reduces cruising for parking. In the peak period, progressive hourly pricing reduces the number of vehicles searching for available parking by nearly **40%**, compared to hourly pricing.
- Slightly lowers the total network travel time and carbon emissions of all vehicles in the network.
- **More than doubles** the collected parking revenue. This results from the higher progressive, optimized rates charged after the first increment of parking duration.

[52] David Ornelas, Mehdi Nourinejad, Peter Park, and Matthew J. Roorda. *Pricing options as a curbside management tactic for the City of Toronto.* York University and the Smart Freight Centre. August 25, 2021.

6. Recommendations

Curbside competition is intensifying in Toronto as transportation behaviours and patterns change; there is a growing amount of rideshare and other economic activity at the curb and a larger volume of delivery vehicles in the city seeking spaces to load or unload. A challenge that the City of Toronto is facing is the fact that the existing curbside parking policy (hourly pricing) is failing to effectively manage high-demand curbside parking on some streets in the downtown core, with some areas being overutilized at 80-100% occupancy during peak hours.

Based on the results of this study of parking pricing options, the Pembina Institute recommends that the City of Toronto **implement a progressive hourly pricing policy** in areas of Toronto, in zones where fees are currently charged for curbside parking. Analysis shows that progressive hourly pricing achieves better results on all accounts than the business-as-usual hourly pricing.

Based on our review of implementation practices of other jurisdictions, the City may want to consider **implementing a pilot project** in a targeted area prior to full program rollout to resolve any unintended outcomes. Best practices show that developing a comprehensive public education and communications campaign on changes to parking policies is key to successful implementation.

Although this study did not evaluate the potential impacts of dynamic pricing in Toronto, research and real-world applications show that this policy approach, like progressive hourly pricing, can also be an effective way to manage curbside activities. Where there is an opportunity to do so, the City may want to consider **evaluating and comparing the effectiveness of a dynamic parking pricing policy** in Toronto.