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WHY AND HOW HIGH-SENSITIVITY GNSS RECEIVERS WILL MAKE PARKING THE DOMINANT NEW TRANSPORT DEMAND MANAGEMENT TOOL

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Abstract

The availability of *high-sensitivity* GNSS receivers coupled with newly developed signal processing and sensor fusion has enabled a new, robust solution to measuring vehicle location in urban areas. This, in turn, enables a reliable, wireless, location anonymous, data service for metering road use so that "same-trip = same charge" can now be guaranteed. This same technology can now meter a parked car to its exact lot/spot, exact time and exact per-minute price. As cities and regions begin to deploy *congestion pricing* systems, there will be a ready-made opportunity for municipalities and private operators to use this same metering and payment service architecture to manage *wide-area, infrastructure-free, hands-free parking*. On this same data aggregation platform it is possible to layer services for pay-as-you-drive insurance. Such a combined payment services platform reduces parking transaction costs virtually to zero and reduces marginal management costs per spot so dramatically as to allow municipalities and private operators to bring far more parking inventory under profitable management. Interest in parking demand management as a critical transportation demand management tool is increasing. With the publication of Donald Shoup's work [**7**] comes an increasing realization that underpriced parking can be a direct contributor to CBD congestion and an invitation to bring private vehicles into the centers of such cites, thereby contributing to interurban and exurban congestion, as well. This paper will detail how parking management can become a critical lever in the fight against urban traffic congestion, as well as briefly discuss the technical innovation that makes this possible.

1 Introduction

As more jurisdictions turn to market pricing as a transport demand management tool, a critical examination of parking pricing will be inescapable. Depending on local, urban regulations, parking may be underpriced, retailers may demand free or cheap street-parking, residential parking may be unmanaged (leading to spillover), enforcement may be minimal, employers may provide free parking downtown, especially in buildings they may own or lease, monthly parking passes may be common, and so on. The number of ways a motorist can externalize her cost of parking is directly related to her contribution to traffic congestion.

While road user charging (RUC) can be a powerful and invaluable traffic demand management tool, I note four key factors (among many others) that generate resistance to this change: 1) many motorists think they already pay the full cost of roads with fuel taxes; 2) road-use payment transactions via fuel taxes are painless, almost invisible, to motorists; 3) collecting fuel-tax payments is virtually free for the road authority; and 4) motorists feel that variable pricing places an additional burden of use-optimization on them (Should I drive? When should I drive? Which route should I take? etc.)

This last point is subtle but critical: commuters prefer to go when, where and how they wish. Other than the fact that most motorists notice the creeping and enduring pain of congestion, few wish to sacrifice the autonomy provided by the private vehicle. So while RUC is proven to work, political and social inertia slows its implementation.

Parking demand management (PDM), on the other hand, has a diametrically opposed set of perceptual factors that make parking less resistant to a change in payment paradigm: 1) most motorists appreciate that parking cannot always be free; 2) parking-use payments via machines and numerous other payment mechanisms, especially including citations for meter violations which are plainly a nuisance, and often infuriating; 3) collecting these numerous and small payments is very costly for parking authorities and operators (on average a parking authority in North America spends about 70 percent of their revenue on the systems and labor to collect that revenue; and 4) motorists are accustomed to spending time and effort on use-optimization of parking.

Again, the latter point is subtle but critical: automotive commuters will seek cheaper parking, they will walk an extra 100 meters, they will arrive early, they will attempt to cheat a meter, they will park free in a retail lot (spillover), they make shopping decisions based on free parking, but most egregiously, they will circle repeatedly around city streets waiting for a cheap short-term parking spot instead of paying the greater expense of

garage parking. In other words, they prefer to personally optimize by using a free resource (whether streets or air quality) rather than spend money on a higher priced resource.

Note, however, these same motorists who “optimize” their parking costs pay far less attention to optimizing their road use – i.e., they less often decide if, where or when they should drive in order to avoid wasting time, burning additional fuel, and contributing to congestion.

2 A new kind of parking payment technology

Before addressing a new parking-pricing paradigm, let’s review what is now possible technically.

The development of reliable road-use and parking-use metering telematics for use in built-up cities (“urban canyon”) has been discussed at length elsewhere [**2,3,4,5**]. As a simple overview, this metering system uses six integrated components to provide a reliable, “Same-Trip, Same-Charge” billing guarantee to any road network tolling operator or in the case of this paper, any parking tolling operator, so that they are able to run reliable billing and payment services in an infrastructure-free environment. These are:

1. *High sensitivity receivers*, which are always able to obtain a position fix, albeit a noisy one, excepting in tunnels and parking garages, which can be repaired on signal recovery.
2. A signal filtering process called *Receiver Autonomous Multipath Mitigation* that includes sensor fusion and a considerable amount of processing to overcome the additional levels of multipath noise from the high-sensitivity receivers [**1,6**].
3. In the case of a parked vehicle, an additional, temporal signal filtering process called *Parking Locator* that zeroes in on an accurate parking location over a few minutes. or,
   In the case of a moving vehicle, this is replaced by a spatial filtering process called *Trip Distance Assurance* that guarantees "Same-trip = Same-distance" for any identical trip (starts and stops in the same places and travels along the same route). This assures repeatability from trip-to-trip and from motorist-to-motorist.
4. A financial rules-based process called *Price Map Preparation* that ensures that the pricing scheme (the "pricemap") is set up to guarantee that no location errors will cause a parking charge error, or,
   In the case of a moving vehicle this amounts to "Same-trip=Same-charge", even in the event of minor spatial deviations and intersecting roads that may be priced differently.
5. A reliability metric called *Integrity Characterization* that is used in conjunction with other system assurances to protect non-refutability of the usages charges that depend on the metering process.
6. A data-management regime called *Privacy Shield* that ensures motorist privacy (i.e., the billing authority cannot access location information and the meter operator cannot access motorist ID. This still allows motorists to self-audit. Data anonymity is also available but this makes self-audit more complex.

This meter is a wireless network-attached data telematics device affixed to a vehicle and is exactly analogous to a handset in mobile phone network, including, optionally, an anonymous node.

2.2 The Data Service Layer

By mimicking already-successful mobile-telephony architecture, it is possible to create a highly reliable data-service layer that provides a scalable billing feed to parking or road tolling operators who would manage payment collection for parking and road tolling authorities. This allows motorists to subscribe to value-laden location-based payment services such as *any* form of parking metering, RUC-metering and PAYD insurance premium metering, and multiple other marketing and location services via a single in-car service portal. In mirror, this also allows network tolling operators to subscribe to disaggregated data feeds in order to service specific tolling authorities or parking authorities under contract.

This architecture automatically provides roaming and cross-jurisdiction payment settlements by using the same methods and systems as are already used in wireless mobility networks and payment settlement agreements. Hence, interoperability among payment operators using the same subscription technology is a given and interoperability with earlier technologies (several forms of curb-side metering technology in the case of parking or manual, RFID, DSRC, I/R in the case of road use) can now be handled purely by payment settlement. Indeed it is possible to replace any instance of existing tolling technology with this single meter while letting the existing system(s) be retired over time.

Specifically, this means that a vehicle (motorist) from Montreal that is subscribed to a local tolling payment service, can park (and drive) in Chicago and payments for parking (and road-use) will be handled by settlements among the several payment operators whose parking (or road) infrastructure he may use during his journey.

In the wireless tolling networks of the very near future most of the heavy lifting will have already been done by cellular providers. To become a Parking or Road Tolling Payment Operator one needs telecommunications

services, a road-use data feed such as described here, a system to admit guests (vehicles without the telematics meter), enforcement, and a billing and customer-support system. Today's cellular network (CN) operators are well positioned to provide such services. To the motorist such a service could behave like a credit or debit instrument and will soon cost as little.

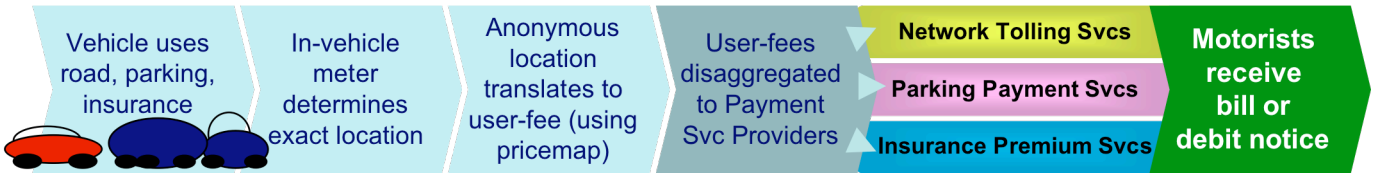

Figure 1: Metering Services can be provided using a network of in-car meters whose wireless data is anonymously translated to a billing feed, disassociated from private location data, disaggregated to individual payment operators and apportioned accordingly to individual infrastructure provider via a rules database (pricemap).

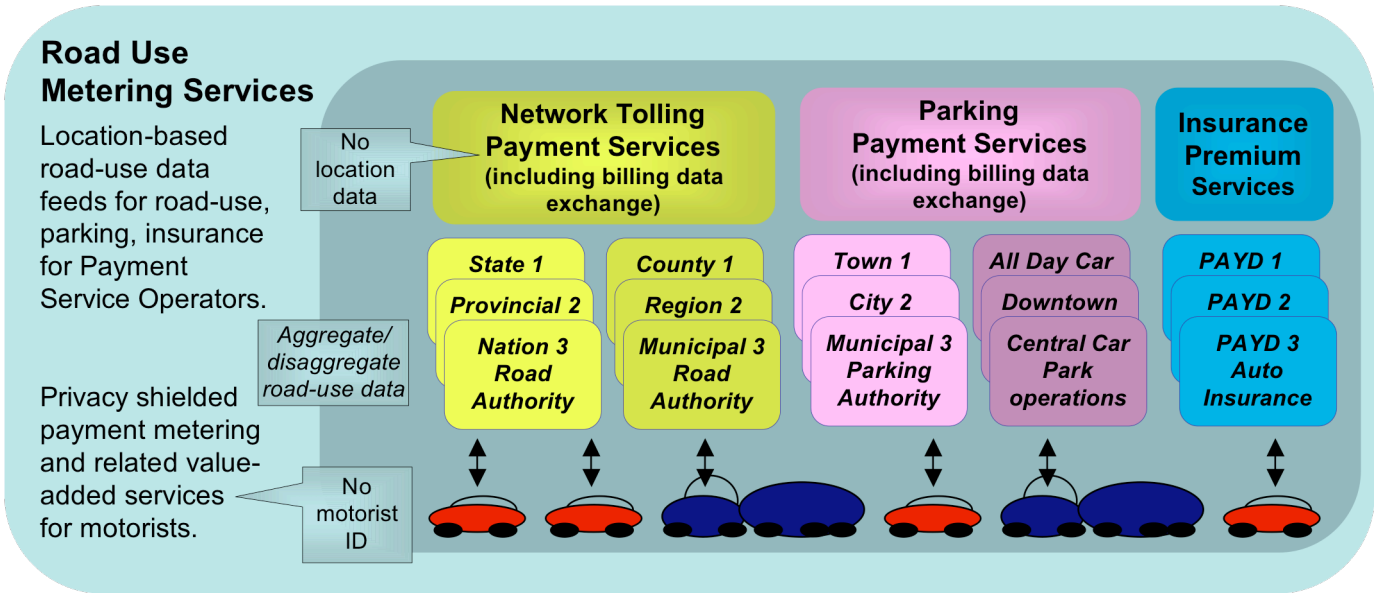

Figure 2: Separating metering services from payment services does four important things: reduces costs, more easily admits value added services (due to data aggregation/disaggregation), increases local competition (including micro-competition for novel services) and provides a privacy barrier.

3 The payment paradigm switch

I previously listed four opposing attributes of how motorists currently pay for road use vs parking use: 1) motorists believe they pay already the full cost of roads with fuel taxes but they realize that they must often pay an additional fee to park; 2) road-use payment transactions via fuel taxes are painless, but parking payment transactions are exceedingly painful; 3) collecting fuel-tax payments is virtually free, but collecting parking fees is very expensive; and 4) motorists currently pay little attention to optimizing road use (since access is free) but often pay considerable attention to optimizing parking use.

Hence, a parking payment system that 1) collected parking payments that motorists already accept; 2) are collected painlessly; 3) are collected at very little expense; and 4) reduce the headache of optimizing (and the revenue loss and congestion caused by that optimization), would be far more acceptable to motorists than would be a new road-pricing system.

Fundamentally, a GPS-based parking payment system would enjoy more acceptance than a GPS-road-user charging system. Such a system could be totally voluntary since locations that currently charge for parking already have a payment system in place. Once such a system is operational, a municipal authority can start addressing its "free parking" entitlements, since it would now have access to a very low cost payment system and enforcement can be designed to be self-funding. As more motorists subscribe to these services, a platform for PAYD insurance is readied. And as the platform becomes prevalent the installed base of vehicles pre-enabled for road-use metering would grow, making a future transition to Time, Distance and Place (TDP) congestion pricing far easier.

In the meantime, long before RUC and congestion pricing is widely deployed, GPS-based parking pricing

can provide an effective, proximate tool for congestion management. That alone should make municipalities consider such systems as an alternate, concurrent parking payment method to existing methods.

3.1 Additional features

In addition to some of the global features listed above, a hand-free, on-board parking meter allows for ticket-free parking. Rather than risk a citation for a meter offence, a vehicle that has over-stayed would simply be charged an escalated per-minute rate. Furthermore, it would be possible to provide a few minutes free to motorists to attract them to a commercial area in satisfaction of retailers demands for free parking. Putting these two together you could, for example, attract shoppers with 30 minutes of free parking, 90 minutes of modestly charged parking followed by any number of minutes of more expensive parking. The modest second-stage charge could be designed to recoup the free 30 minutes and the escalated, third-stage charge would be designed for high turnover, and as a replacement for citation revenue. All of the attendant parking rates would be set in a database and administered according to local needs. The only street infrastructure would be signage explaining the local rates. With variable signage, a municipality could even deploy realtime pricing in high-demand areas.

For residential parking, it would be possible to charge all residential streets rather than only the busier thoroughfares. For example, in some cities streets near commercial areas may be "one-hour free", but are sometimes rarely patrolled. These could still be one hour free, but charged thereafter. Ticketing would only be for those that were not using a working meter.

Many residential areas controlled by permit require guests to leave at, say, midnight, or risk a fine. Such streets could be priced modestly throughout the day and more aggressively after midnight (residents exempt). Indeed, this could be scaled to suit the neighborhood. Parking management costs would be dramatically lower than with street meters such as pay-and-display, hence allowing effective management of previously marginal parking areas.

GPS-for-Parking makes it possible to build and operate a cheap proxy to a congestion pricing system without additional cost above that for the PDM system – i.e., a proximate form of congestion-pricing can commence now while waiting for RUC to deploy:

- Charge a parking premium to a motorist who commenced or ended a parking episode during peak hours, even if the parking spot is free or in-doors [option], since that implies use of roads during peak hours.
- Provide a parking credit to any motorist whose vehicle was not moving during peak hours, regardless of whether its owner drove before or after peak hour or whether he took the bus or stayed home.
- Price hundreds of thousands of currently unpriced spots that are in residential areas or commercial courtesy lots that might now be unmarked or marked "no parking", "one-hour parking", or "no parking before 10am" for paid use by visitors or commuters who come part way from the suburbs to a convenient transit stop. This could raise revenue where there was none before, and provide incentives for those with poor transit service at their home neighborhood to drive part way and use transit for the remainder of the commute. This benefits them and the city.
- Charge courier and other delivery vehicles by-the-minute to stop on busy streets. The right fee would incentivize couriers to schedule, park and deliver differently – while passing on the expense to their customers.

4 Summary

Affordable (self-funding) congestion management is now possible in a more politically palatable package, making it is possible to raise revenue, reduce congestion, increase motorist comfort with satellite metering, gradually eradicate free parking, and build a *voluntary* installed base of GPS Parking/RUC meters. For these reasons parking management will grow in relative importance as a demand-management tool.

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