Designing dynamic pricing for on-street parking

Brochure
What is dynamic pricing and why do it?

On-street parking in large cities can be an expensive headache. However, the installation of parking sensors in cities such as Los Angeles and San Francisco promises a better trade-off between prices and the ease of finding a parking space. These sensors track the occupancy (exactly how many vehicles are parked) of each block face (the portion of a street between two other streets). The purpose is to dynamically set prices so that the occupancy of each block face equals some occupancy target, such as 70% or 80% full, throughout the day.

When we say that prices change dynamically, we mean that a timetable of prices is fixed in advance and is changed every few weeks. We are not talking about the sort of hard-to-predict minute-by-minute price changes that are common for air fares, which would make drivers’ lives even more complex. For instance, imagine you were happily parking on a street that usually costs $5 per hour and as you stepped out of the car, the price shot up to $15 per hour!

Controlling prices for a scarce resource is called demand management, and demand management for on-street parking can have numerous benefits. Where prices are lowered there is better utilisation of existing space. Where prices are raised, it becomes easier to find a space, for those who are willing to pay the price. This can have the consequence that there are fewer vehicles circling around looking for a space, slowing down other traffic and causing congestion, pollution and hence health problems, as well as wasting other drivers’ time. Additionally, as prices increase, some drivers shift to greener modes of transport, such as sharing vehicles, public transport or cycling. Depending on the choice of occupancy target, both increases and decreases in price can result in more revenue for a city. For instance, if prices are lowered, there is typically an increase in demand which may offset the lower price paid per driver.

A less obvious but equally important benefit of dynamic pricing is that it raises the political decision about parking prices to a higher level. It is not reasonable to expect such decisions to be made for 1000 block faces every month, although an appropriate choice of prices may well vary from month to month. In contrast, appropriate choices of occupancy targets are rather more stable over time. Thus, if we make political decisions about occupancy targets rather than prices, then those decisions need only be revisited rarely, and dynamic pricing can be used to ensure that the targets are met.
There is a simple approach to dynamic pricing that exists today, which scales to thousands of block faces, is easy to communicate and is fairly effective in tracking the evolution of demand. This approach, known as the occupancy thermostat, just raises prices when the average occupancy over the last month was significantly above target and lowers prices when the average occupancy over the last month was significantly below target. For instance, one might raise prices by 50¢ per hour if occupancy was over 80% and lower prices by 50¢ if occupancy was below 60%.

This approach is not without limitations. Firstly, occupancy may oscillate rather a lot. Consider the following simple example. Say there are two nearby block faces, initially priced at $3.50 and $3 per hour and people are parking for about six hours. Most people would prefer to pay 6 hours × 50¢ = $3 less and walk from their parking space to their actual destination. So, if during one month the occupancies of the block faces are 50% and 90%, then the prices will adjust by 50¢ to $3 and $3.50 per hour for the next month. So, the occupancies themselves will reverse to 90% and 50%, leading to an oscillation.

A more significant limitation of the occupancy thermostat is that it is not possible to predict future occupancy given large but foreseeable time variations. For instance, one would like to be able to predict the impact of road closures, seasonal variations and holidays, and to set prices accordingly. Moreover, one cannot predict the effect of price changes on congestion, revenue to the city and illegal parking behaviour. Another limitation is that one cannot meaningfully ask the question “What are appropriate occupancy targets?” To answer this question one has to take into account how much people value their on-street parking spaces relative to other options such as public transport and off-street parking, as well as gauging the impact of occupancy targets on local businesses.

To address such limitations, it is necessary to build models of how demand varies with price. The dynamic pricing problem then quickly becomes challenging. The first challenge is to design an appropriate model of how people choose parking spaces. It is straightforward to make a choice model that accounts for willingness to pay and willingness to walk. However, to make reliable predictions one must also account for the immense flexibility that drivers have about where, when, for how long they stay and for what portion of their stay they are parked legally. We must recognize that populations react gradually, rather than instantly to price changes. We must also acknowledge that drivers sometimes have to revise their decisions because the block face they wished to park on is currently fully occupied.

Given such a model, one must estimate its parameters from a history of observations and optimize prices accordingly. These tasks are computationally difficult for a large city because of the huge number of possible choices of location, arrival time and parking duration, and because the whole system has a complicated dependence on its own history. For instance, the actual behaviour of driver Alice, who arrives at 11 am, depends on the behaviour of drivers Bob, who arrived at 9 am, and Cindy, who arrived at 10 am, since those drivers may have fully occupied the block face where Alice first wished to park.
The Xerox approach to on-street parking follows our “City Manager Dashboard” vision. The idea is to enable city administrators to make good overall decisions that integrate information about public transportation and parking by combining data from parking sensors, parking enforcement officers and surveys, with variables such as weather, street closures, holidays and local business activities. We provide special techniques to overcome the imperfections of such data sources. For instance, while parking sensors have reached a high degree of accuracy, it is still necessary to account for errors and noise, such as spurious sensor readings caused by passing traffic, that would otherwise corrupt estimates of occupancy.

We combine data from sensors, surveys, weather and holidays.

Our approach couples simple-to-understand occupancy-thermostat pricing with sophisticated model-based estimation, prediction, simulation, visualization and pricing. The models exploit novel approximations related to those used to model call centres and to model telecommunications traffic in order to predict demand even when streets might become fully occupied. Simultaneously, our models exploit state-of-the-art choice models that have been recently invented in marketing in order to capture the heterogeneity in people’s preferences. Given these choice models, we can predict the value of a given price schedule to drivers and to local businesses, so that future choices of occupancy targets may be refined to maximize this value.

In the past, parking prices were not well-adapted to demand, resulting in economic inefficiencies and making parking an expensive headache. Dynamic pricing promises to be more effective than aspirin in getting rid of the headache, while making on-street parking economically efficient.

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