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Project Title

Testing Irrationality in Metered Parking Payment Compliance

University

University of Colorado Denver

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Research Needs

In urban areas across the U.S., a cutting-edge trend in parking management is to combine new technologies and market mechanisms to manage demand, reduce automobile use, congestion, and pollution. For example, in 2011, San Francisco launched one of the most complete smart parking pilot programs with a $19.8 million grant from the U.S. Department of Transportation (U.S. Department of Transportation, 2014). The system used dynamic pricing, communication technologies (e.g., parking app), and street-level hardware to allocate parking spaces more efficiently.

According to official evaluations of San Francisco's pilot program, the dynamic pricing was most effective when the payment compliance rate exceeded 85% (i.e., when drivers paid the meter for at least 85% of the time they parked). Yet, on average, users paid the meters only about 50% of the time (San Francisco Municipal Transportation Agency, 2014). This reality presents an obvious irony: If people were not paying the meter, how could they respond to dynamic pricing? When people do not pay for parking, pricing loses its effectiveness as a market mechanism to regulate parking behavior.

Modern smart parking systems use a mix of regulatory and market-based approaches to manage demand. Unfortunately, they still treat payment compliance as an old-fashioned enforcement problem (U.S. Department of Transportation, 2017; U.S. Department of Transportation, 2015;

Daniel, 2014; SFMTA, 2014; Dion et al., 2011; Seattle Department of Transportation, 2011; Washington, D.C., 2008). Market-based approaches to parking may need to move beyond the traditional model of enforcement to achieve higher payment compliance rates. Yet, first, we need a behavioral understanding of parking payment decisions.

Parking payment non-compliance behavior is the central problem addressed in this proposed research. Parking payment decisions are complex, poorly understood, and understudied. Most existing research on parking payment non-compliance either assumes that the driver is rational and that payment non-compliance is intentional (Cullinane, 1993), or it treats the driver as a black box, examining the phenomenon with no interest in understanding the behavior (Yang and Qian, 2017). This proposed research studies parking payment non-compliance behavior using data from the city of Denver and theories of behavioral economics. Our goal is to understand the behavioral patterns of payment non-compliance, and to test whether such behaviors are motivated by the driver's rational analysis of cost and benefit.

Brief Review of the Literature

Field studies of on-street, metered parking from the Seattle and San Francisco smart parking programs indicate that payment non-compliance is prevalent. In the San Francisco pilot program, the payment non-compliance rates across the seven study areas ranged from 68% in Downtown (highest) to 32% in the Marina (lowest) before the pilot program, and 61% in Downtown (highest) and 34% in the Marina (lowest) after the pilot (San Francisco Municipal Transportation Agency, 2015). In Seattle, field studies of payment non-compliance showed similar patterns, where non-compliance rates ranged from 63% in First Hill (highest) and 0% in Fremont (lowest), with an average of 31% across the 16 sites that had sufficient data (Seattle Department of Transportation, 2011).

The peer-reviewed transportation, economics, and engineering literatures have analyzed the driver's parking search decision empirically and analytically, but the driver's parking payment decisions have rarely been addressed (Inci, 2015; Arnott, 2014). In recent examples where payment compliance has been examined, it was used indirectly to improve estimates of physical occupancy rates and traffic congestion (Yang and Qian, 2017; Petiot, 2004) but it has not been examined as its own behavioral phenomenon.

Certain social psychology, economics, and transportation studies have framed the payment non-compliance problem as an example of deviant behavior (Adams and Webley, 1997). Such behavior is subject to deterrence through enforcement, which involves its own set of tradeoffs between public costs and benefits (Shoup, 2011; Black et al., 1993a; Gibbs, 1986). Other types of deviant behavior included in this category are parking in loading zones, sidewalks, or handicapped spaces, as well as speeding (Barracho Oliveira, 2016; Morillo and MagÃ-n Campos, 2014; Cope et al., 1991; Suarez de Balcazar et al., 1988; Rothengatter, 1982).

A major limitation of the existing studies on parking payment non-compliance is that they assume perfect rationality, arguing that people will not pay for parking if it is not in their economic interest (Shoup, 2011; Black et al., 1993a; Black et al., 1993b). This is typical of most public policy analysis, which assumes that people will make rational decisions about social problems based on the cost-benefit ratio of the action. However, the recent few decades of research in psychology and behavioral economics has shown that real behaviors are not perfectly rational, and sometimes they are even “irrational” (Ariely, 2008; Kahneman, 2003; Tversky and Kahneman, 1981; Tversky and Kahneman, 1974). For example, people donate more money to one identified child in need than they donate to a group of anonymous children in a similar situation (Kogut and Ritov, 2011). Similarly, we all know a story of someone buying a gym membership and never using it. These behaviors are irrational: All else being equal, the needs of many children clearly exceed the need of one child; and paying for a gym membership without using the gym is an economic loss with no benefits. Because many behaviors are irrational, we cannot assume that parking payment decisions are necessarily rational. Therefore, the objective of this research is to test whether underpaying for parking, or not paying at all, makes sense under conditions of perfect rationality. The findings can be used to design parking regulation and pricing regimes that nudge drivers toward parking payment compliance, potentially increasing social welfare.

Research Objectives

1. Create a typology that describes the different modes of parking payment non-compliance (e.g., paying too little within maximum time limit, exceeding time limit, not paying at all), and quantify the magnitude and spatial-temporal distribution of the types of non-compliance that we observe.
2. Test whether payment non-compliance is rational for the driver based on standards of classical economic theory.

In this research, we examine parking payment behavior through the lens of behavioral economics. We collaborate with the City of Denver to use detailed meter transaction, surveillance, and citation data to: (1) analyze the existing patterns of parking payment non-compliance, and (2) test whether the nonpayment and underpayment behavior is consistent with the assumption that people make rational decisions based on cost-benefit analysis.

Aim 1: We will create a typology that describes the different modes of parking payment non-compliance (e.g., paying too little within maximum time limit, exceeding time limit, not paying at all), and we will quantify the magnitude and spatial-temporal distribution of the types of non-compliance that we observe.

Aim 2: We will test whether payment non-compliance is rational for the driver based on standards of classical economic theory. We hypothesize that it is not. That is, on average, we expect that drivers do not “outsmart” the system, and that they incur more cost from the probabilistic citation than from their parking payment.

Our first aim is descriptive and involves establishing the parameters of the parking non-compliance problem for the case of Denver. Because the parking non-compliance problem has not been studied before, it is necessary to characterize the general problem from the driver’s perspective and from the city’s perspective. Our second aim is explanatory and involves statistical analysis of parking, surveillance, and citation data to test the hypothesis that parking underpayment/nonpayment is irrational.

Research Methods

Study Area

Our study area is a zone within downtown Denver, "Lower Downtown." Lower Downtown is an important regional activity center, with a mix of commercial and residential land uses that attract daytime and nighttime trips. This results in intense demand for parking that our partners at the Denver Public Works Transportation and Mobility department are actively managing.

Data

Because Lower Downtown is an important regional center, and because the Denver Department of Public Works Transportation and Mobility are actively managing parking in this zone, we have access to high-quality meter transaction data, citation data, and enforcement surveillance data necessary to carry out Aim 1 and Aim 2. Meter transaction data include variables such as meter identification number, parking start and end time and date, total amount paid, and method of payment. Citation data can be linked to meter transaction data by the meter identification number, date, and time. Surveillance data indicate how much time a parking enforcement officer spent observing each metered space, which is the measure used to normalize citations to create a citation rate.

Despite the rich secondary data available, we need to collect primary data in the field to estimate the "true" physical occupancy and paid occupancy to compute the payment compliance rate in Aim 1, and to analyze decision to choose unpaid parking in Aim 2. We also need these data to compute the real citation rate normalized by actual surveillance in Aim 2.

The collection of field data involves creating an appropriate sampling strategy, creating a data collection protocol and form, testing the data collection instruments, training student researchers to carry out the observations, data entry, and quality control. Variables we anticipate collecting through field methods include: parking arrival times, departure times, and physical occupancy; parking meter payment and paid occupancy; actual surveillance rate and actual citation rate. From these we will also construct the meter overstay rate, which is less than or equal to the actual citation rate. We will use these "ground truth" data for sampled sites to estimate metrics for the study area.

If at any point in our study sensor-based occupancy data become available, and if the sensor data are a perfect substitute for our field data, then we would potentially stop collecting field data.

Analytical Approach

In reality, parking is more like a game than a straightforward economic good. In this game, people search and pay for a vacant space, and they engage with an array of heuristics, regulations, and potential sanctions when they decide how much parking time to purchase. Given a driver has successfully completed the search process, if the driver does not pay or underpays, it means the driver must have computed the cost (expected disutility of a citation) and benefit (expected utility of saved parking cost) of such behavior, and concluded that the best strategy in this game is to not pay or underpay the meter. Yet, data show that drivers in San Francisco paid 64% more in parking citations ($88,261,220) than they paid in meter fees in 2015 ($53,738,314)

(SFMTA, 2016). This is initial evidence that people may not be outsmarting the system, or that they are not making a “rational” decision as suggested by classical economic theory of behavior.

To formally test our hypothesis, we examine the decision between paying and not paying for parking fee given that the car will be parked. Here, we need to compare the potential cost of meter payment (consequence of paying the meter) to the probabilistic cost of citation (consequence of not paying the meter). Based on Expected Utility Theory (von Neumann and Morgenstern, 1947), the choice to not pay the meter implies the following: The expected utility (EU) of not paying for parking (risking a citation) is greater than the expected utility of paying for parking. Formally stated:

Equation 1: EU (meter fee) [less than] EU (probabilistic citation), or
Equation 1a: U (meter fee) [less than] U (citation fee) * P (citation)

Where: EU refers to the expected utility of an outcome given the probability of the outcome. U (meter fee) is the negative utility of meter fee, U (citation fee) is the negative utility of citation fee, and P is the probability of receiving a citation.

For example, assume the meter fee is $2 for the parking period, and the citation fee is $100 with a probability of .01 for the parking period. Because both the meter fee and the citation incur a loss, the utility calculations can be written as follows (for a basic test, we equate utility to the dollar amount value of money):

EU (meter fee) = U (-$2) = -$2
EU (probabilistic citation) = U (-$100) * .01 = -$1

Because -$2 [less than] -$1, Equation 1 is satisfied, and the expected utility of risking a citation is better. Therefore, we would claim that the decision to evade parking fee is rational.

In an opposite example, assume the meter fee is $2, and the citation fee is still $100 but with a probability of .20. The utility calculations can be written as:

EU (meter fee) = U (-$2) = -$2
EU (probabilistic citation) = U (-$100) * .20 = -$20

Since -$2 [greater than] -$20, Equation 1 is not satisfied, and the expected utility of risking a citation is worse than the expected utility of paying for parking. Therefore, we conclude that the decision to evade parking fee an irrational one.

In this project, we test whether, in reality, real parking payment behavior conforms to the rational standard (Equation 1) using secondary and primary data from the city of Denver. We will compute real probability of citation based on field studies and secondary data, and obtain actual value of citations issued, and actual value of the parking fee from the city of Denver. Our hypothesis is that, on average, actual parking payment behavior will not satisfy Equation 1, and the decision to evade meter payment generally backfires and leads to worse financial outcomes.

Expected Outcomes

The expected outcomes of this work include:

1. Findings for Aim 1 and Aim 2.
2. A plan for scaling up this study plus refined research questions and methods to pursue in future work. We expect these data to be "preliminary" data necessary for a National Science Foundation-funded study that aims to establish key behavioral theories suitable for explaining parking payment non-compliance.
3. A manuscript for presentation at TRB and one or more manuscripts targeting peer-reviewed journals.
4. A presentation for local academic, planning, and policy audiences in Denver.

Relevance to Strategic Goals

- Economic Competitiveness
- Livable Communities

The work advances three U.S. Department of Transportation strategic goals: livable communities, economic competitiveness, and environmental sustainability. Parking management is critical to the economy, quality of life, and environmental sustainability because of its wide-ranging implications for travel demand management and traffic operations. The contribution of this research project is to integrate these transportation goals within a new behavioral framework that takes into consideration irrational, real-world parking behavior. This framework can be applied to other key infrastructure systems, including the broader questions of behavioral implications of connected and autonomous vehicles systems.

Educational Benefits

This study offers unique educational benefits in transportation, economics, and behavioral sciences. This is a novel and essential combination of theory and application that will prepare future practitioners in multiple fields. Dr. McAndrews will integrate this research into the module of travel behavior currently offered in her Transportation and Land Use course, as well as the module on parking currently offered in her Urban Economic Analysis course. Dr. Li will integrate this research into her courses on Decision Making and Health Policy. The data collected for this project will also be made available to students for use in term projects and master's reports.

Technology Transfer

Technology transfer is an essential part of this project as we expect that this approach could be commercialized as part of the business intelligence analytics that is currently part of smart parking systems. Our intellectual property would be the methodology for introducing behavioral theory into the machine learning that contributes to parking management. We are currently working under nondisclosure agreements with our partners.

Work Plan

1. IRB review
2. Literature review
3. Collect and assemble secondary data
4. Develop and test field data collection plan
5. Conduct field data collection
6. Integrate field data with secondary data
7. Data analysis
8. Develop plan to scale the analysis
9. Draft manuscript and presentation materials

The proposed scope of work has a one-year timeframe, beginning with notice to proceed from the Mountain-Plains Consortium. Major project steps include the following (Table 1):

Table 1. Work Plan with Project Steps and Timeline

Project steps	Timeline
IRB review	Submit before project start date
Literature review	Months 1-2
Collect and assemble secondary data	Months 1-2
Develop and test field data collection plan	Months 1-2
Conduct field data collection	Months 3-6
Integrate field data with secondary data	Months 3-6
Data analysis	Months 1-12
Develop plan to scale the analysis	Months 1-12
Draft manuscript and presentation materials	Months 1-12

Before beginning our project, we will seek review from our Institutional Review Board.

During the initial months (months 1-2), we will conduct a thorough literature review, collect and assemble the secondary data, and develop and test our data collection plan for field data. Next, we will collect field data and integrate them with our secondary data (months 3-6). Throughout the project (months 1-12) we will be carrying out various stages of the data analysis, developing a plan to scale the analysis, and drafting manuscripts and presentation materials.

Appropriate findings from this study will be published in peer-reviewed journals, and/or peer-reviewed conference proceedings, as well as presented at various conferences including the Transportation Research Board Annual Meeting. This work will also be disseminated to the public works and city planning departments in Denver and other local and state agencies.

Certain findings related to the commercial value of this research may be kept confidential and used to apply for a patent. We are working with the Technology Transfer office at the University of Colorado to inform this process.

Project Cost

Total Project Costs:	$120,000
MPC Funds Requested:	$ 60,000
Matching Funds:	$ 60,000
Source of Matching Funds:	University of Colorado Denver

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