REDUCING ROAD CONGESTION THROUGH INCENTIVES: A CASE STUDY

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ABSTRACT

Traffic congestion is a burden on modern society: hundreds of billions of dollars are wasted each year due to extra fuel consumed, wasted time of commuters, traffic accidents, etc. Congestion occurs when the demand for transport capacity exceeds supply either in a sustained manner each day or just during peak hours. In the former case it is necessary to add transport capacity, whereas adding capacity to combat peak-hour congestion can be very expensive and create a vicious cycle which attracts "latent demand" to fill in the added capacity. Peak-hour demand must therefore be actively managed. Currently, several cities and agencies employ congestion charging which, while effective, often lacks popular support. In this paper we describe an approach that uses incentives to nudge commuter behavior towards congestion-reducing times and modes of travel. Specifically, we describe an incentive program, CAPRI (Congestion And Parking Relief Incentives), which aims to reduce peak-hour traffic in Stanford University. CAPRI rewards commuters who drive during off-peak hours and those who walk or bike to work. Commuter behavior is monitored using RFID sensors for automobiles and a smartphone app–*My Beats*–for walkers and bikers. A commuter who signs up for CAPRI earns points for the "good trips" she makes, and these points can be redeemed for rewards (both monetary and in-kind) in a fun, online game. CAPRI also nudges commuters through features like personalized offers, social influence and status. The paper describes the program, highlighting the effect of each of these features in nudging commuter behavior.

Keywords: Traffic Congestion, Travel Demand Management, Incentives, Personalization, Social Influence, Behavior Shift

1. INTRODUCTION

Traffic congestion is a serious problem occurring every day in cities around the world. According to a recent study (*1*), congestion-related costs surpassed $121 billion in the US in 2011, and this figure is projected to jump to $199 billion by 2020. The consequences of traffic congestion include increased air pollution, extra fuel consumption, increase in traffic accidents, and the diversion of commuters' time from more desirable pursuits.

Given the severity of the problem, cities and transport agencies are employing various methods of addressing congestion. The methods can be classified into two broad categories: increasing transport capacity and curbing the demand. It is necessary to increase transport capacity when the demand exceeds the supply in a sustained fashion and this is expensive; for example, Illinois has a plan underway (*2*) to widen tollways in the Chicago region at a projected cost of $12 billion. Adding capacity to address just peak-hour congestion can not only be prohibitively expensive, it can create a vicious cycle of attracting additional peak traffic—the so-called "latent or induced demand"—and drive the transport system back to a state of congestion (*3*). Hence, peak demand must be actively managed and reduced. Several demand management schemes have been studied and deployed; notably, (a) congestion charging—levying a charge on peak-hour commuters, (b) road rationing—forbidding road use for vehicles on some days depending on license plate numbers, (c) carpool lanes—restricting highway lanes for single occupancy vehicles, (d) ridesharing and vanpooling—encouraging commuters to share vehicles, and (e) travel mode-shifting programs—encouraging commuters to use public transit or bikes. The effectiveness of these measures ultimately rests on the commuters' willingness to support and adopt them.

This paper studies the use of incentives to increase the willingness of commuters at Stanford University for adopting certain congestion-reducing behaviors. Specifically, we aim to reward commuters who travel during off-peak hours (in the shoulder hours adjacent to the morning and evening peak hours) and those who walk or bike to work. Thus, in terms of reducing peak traffic, our approach can be viewed as the complement of congestion charging schemes. Vickrey (*4*) was an early and remarkably prescient proponent of congestion charging. He pointed out that road congestion is an example of the "tragedy of the commons (*5*)" effect: a free public good (namely, the road) will tend to suffer from overuse. Therefore, he argued, congestion charges need to be levied to operate road networks at loads well below the point at which they are congested. Several cities (*6,7,8*) have implemented "congestion charging" mechanisms; essentially, drivers pay a fee for entering *congestion zones* or using pre-designated roadways during peak hours. However, congestion charging schemes can suffer from a lack of popular support and thereby fail to be implemented in the first place (see (*9*), for example).

By being a "carrot" rather than a "stick", incentive approaches are viewed favorably by commuters and, therefore, enjoy certain advantages over congestion charging schemes. Participation in incentive programs is voluntary and on an opt-in basis. Therefore, incentive programs are incrementally deployable, i.e. it is not necessary to include all commuters at the outset. On the other hand, for reasons of fairness, congestion charging schemes must include all the concerned commuters. Incentive programs invite commuters to reveal their good commuting behavior so they may claim rewards rather than go to great lengths to hide their bad behavior so as to avoid charges and penalties. This can considerably reduce the burden of enforcement.

The major questions for a commuter incentive program are: (i) is it effective in inducing the right behavior, and (ii) if so, at what monetary cost? An experiment conducted at a reasonable scale is necessary to answer these questions. This paper describes such an experiment, called CAPRI (Congestion And Parking Relief Incentives), which we have designed and implemented at Stanford University (*10*). The aims of CAPRI are to nudge Stanford University drivers away from peak-time travel, to park at underutilized parking lots and to adopt alternate modes such as biking and walking. The nudges are administered through a combination of monetary rewards, social influence and personalized recommendations.

CAPRI was launched in April 2012 and invited the participation of about 10,200 permit-holding car commuters at Stanford; of these, 3,082 registered for the program. An additional 975 registered for the walking and biking incentives using a smartphone app. We describe the main elements of the CAPRI program and the technological platform, which is a combination of RFID and smartphone-based sensing of commuter movements, and a cloud-based incentive or "nudge" engine. CAPRI builds on the INSTANT (*11*), Steptacular (*12*) and Insinc (*13*) programs in terms of the behavioral interventions and technological elements. The rest of the paper analyzes the commuter behavior shift in detail. We summarize the main findings as follows: compared to the general Stanford population, CAPRI participants are 21.2% less likely to commute during the morning peak hours of 8–9AM, and 13.1% less likely to commute during the afternoon peak hour of 5–6PM. CAPRI also successfully converted tens of commuters from driving to walking or biking to the campus. Through a regression analysis, we show that incentives have played an important role in shifting the commuting behavior of CAPRI participants over time.

2. LITERATURE REVIEW

Incentive programs for reducing congestion. Spitsmijden (Dutch for "peak avoidance") is a series of commuter incentive program conducted in the Netherlands to reward drivers for driving during off-peak hours. It was shown that positive incentives were able to reduce the amount of peak traffic by around 60% (*14,15,16*) in the test population of 340 participants. The rewards in the ten-week program were high: from 3 to 7 euros per avoided peak-hour trip. Sensors were deployed on the road system and in the vehicles of the participants for behavior detection. An experiment in Osaka, Japan gave drivers a one-month free bus ticket. It was observed that drivers who were given free bus tickets took buses more frequently than before, but the effect did not persist after the trial (*17*). A similar study in Germany investigated the effect of offering pre-paid bus tickets to college students (*18*). In Melbourne, Australia, an incentive program offered free rail fares to rail travelers who completed their trips before 7AM in order to alleviate the overcrowding issue during morning peak hours (*19*). A similar program is currently underway in Singapore (*20*).

A recent mobile traffic app, Smartrek, was designed to predict the length of commute time with different departure times, and give varying levels of reward credits to users choosing different departure times (*21*). The prediction of future traffic conditions and suggestion of routes used both historical and real-time traffic data. The program ran for 10 weeks and gathered 308 completed observations. It was found that users were willing to change departure times and routes for as many as 35% of their trips.

Incentive programs for influencing driver behavior. There exists research that focuses on using insurance-based incentives to influence the driving behavior of participants. Usage-based insurance (UBI), for example, uses devices plugged into a car's diagnostic port to record and analyze information such as distance driven, the time at which the trip was undertaken, and unsafe driving behaviors (e.g., hard braking). These data are used to improve the risk profile of the insured and offer potential discounts in insurance premiums. One experiment showed that drivers who were offered mileage-based insurance premium on average drove 5%, or 560 miles, less per year (*22*).

Since the advent of smartphones, there are an increasing number of applications of smartphone apps to monitor commutes and encourage environmentally friendly traffic modes. UBIGreen is a smartphone app that senses users' transportation behaviors and gives graphical feedback (*23*).

As compared to these programs, the scale of the CAPRI program is higher in terms of the number of participants (excluding the Melbourne and Singapore public transit early travel incentive programs), the number of trips observed, and the duration of the project. Secondly, and in common with some of the above programs, CAPRI has made extensive use of technology for sensing (a custom-designed RFID system, and mobile app) and for interaction with the participants (an "always on" online portal). Finally, CAPRI gives monetary rewards through a lottery-like random reward mechanism rather than deterministically. This has allowed CAPRI to use a budget of just $1/participant/week (or 10 cents per morning or evening trip) for nudging.

3. DESIGN AND IMPLEMENTATION OF CAPRI

Background and motivation

Stanford University is one of the largest employers in the San Francisco Bay Area (*24*), and its growing population has led to an increase in traffic volume. This has caused congestion on the roads around the campus and strained the parking resources on campus. Stanford University signed a General Use Permit (GUP) with the County of Santa Clara in 2000 (*25*). One of the provisions in GUP states that Stanford is required to manage its transportation impact under a "no net new commute trips" standard: the amount of traffic during peak hours must not increase by more than 1% over 3,319 vehicles in the morning peak hour, and 1% over 3,446 vehicles in the afternoon peak hour (these numbers were measured in 2000). Failure to adhere to this standard has severe consequences for Stanford, including fines and the refusal of building permits for new construction projects.

Existing efforts to mitigate the traffic in Stanford include free campus shuttles from and to nearby transit stations, cash incentives ($300/person/year) to off-campus staff and students who do not buy parking permits on campus, subsidized public transit passes, and discounts on parking permits for carpooling commuters. These measures have been effective in reducing the total number of commuters who drive alone. It does not directly address peak-hour commuters whose number has been increasing over time. The CAPRI program directly addresses peak-hour commuters and aims to reduce their number.

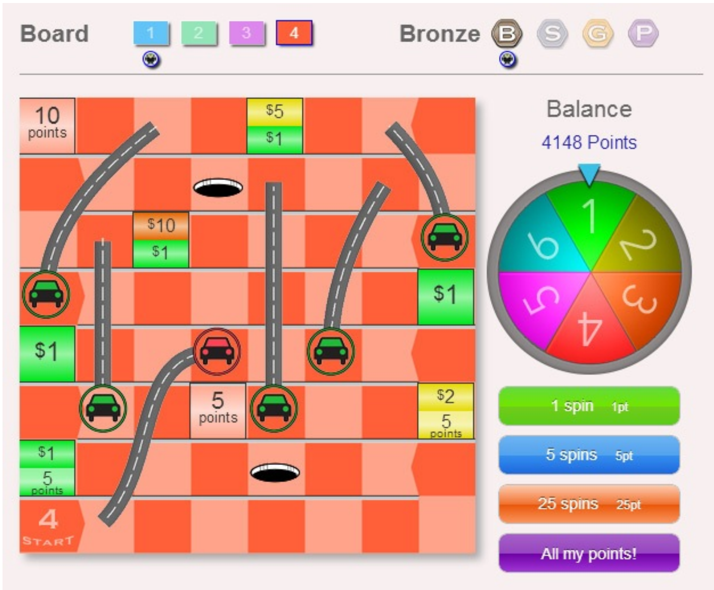

FIGURE 1 Chutes-and-ladders game for redeeming cash reward in CAPRI.

Design

Stanford University parking permit holders who parked inside the "congestion cordon" were invited to participate in the program on Apr 2nd, 2012. Those who enrolled were given passive RFID tags to place on their windshield. The tags were sensed at ten main entrances/exits of the Stanford campus. The sensors detected participants' vehicles for 3 hours in the morning (7–10AM) and in the afternoon (4–7PM) on each weekday. The peak-hours were defined to be 8–9AM and 5–6PM. For each automobile detected by the sensors during the off-peak shoulder hours (7–8AM and 9–10AM, and 4–5PM and 6–7PM), the participant was awarded 10 points. Additionally, CAPRI assigned each participant a *boost day,* a day on which their off-peak trip earned them 30 points. From May 14th, 2013, CAPRI incentivized walkers and bikers by awarding them between 10 and 25 points depending on the length of the commute. Walking and biking activity was monitored using a smart-phone app, called *My Beats*. The CAPRI program concluded on Sept 30th, 2014.

Participants can redeem their points for cash in one of two ways: (i) deterministically, by trading 100 points for $1 (or a full week's worth of off-peak trip points, ignoring boost points), and (ii) randomly, by playing a chutes-and-ladders game using their points on the CAPRI website (FIGURE 1). Playing the game is tantamount to a "self-administered lottery". The game gave cash rewards ranging from $1–$50. 87.3% of the participants used the random rewards option. Since participants were allowed to change the manner of redeeming rewards (deterministic or random), it is interesting to note that 13.2% of the participants chose to switch from the deterministic option to the random option at some point during the program. The rewards were paid out as paycheck supplements or through bank deposits.

CAPRI used a number of other interventions to increase the popularity (and hence the enrollment through friend recommendations), engagement and behavior shift among the participants. We review the important ones below.

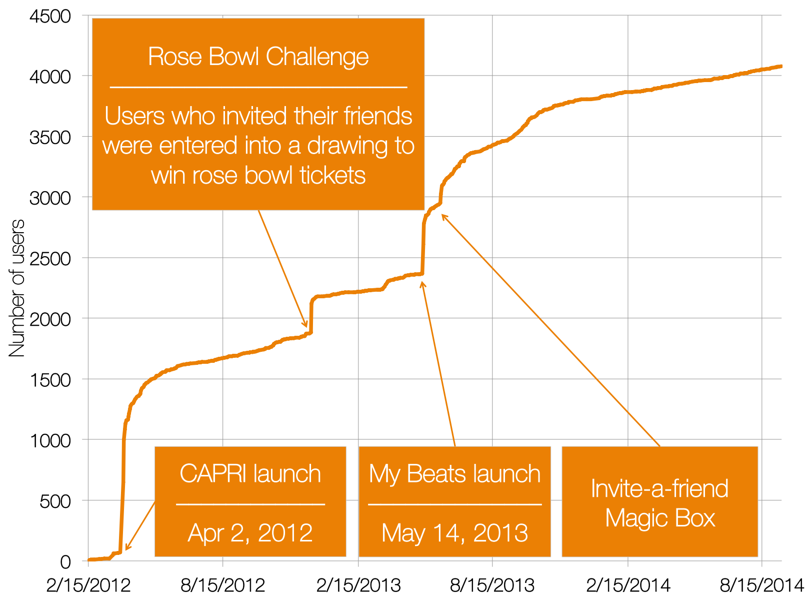

FIGURE 2 Number of CAPRI registrants over time

*Status system***.** Participants were placed in one of four status levels: Bronze, Silver, Gold, and Platinum. Participants started at the Bronze level. Depending on the number of off-peak shoulder hour trips they made on a weekly basis, they could upgrade their status from their current level to the next. At the Silver, Gold and Platinum levels, failure to make the number of off-peak shoulder hour trips required for that status level results in a degrading of the status by one level.

Status is only worth something if it affords a privilege; CAPRI used status as follows. Participants with higher status had higher odds of winning rewards in the game. Further, higher-valued rewards were only available at the higher status levels. For example, the $50 reward was only available at the Platinum level. These two features—higher status means higher odds of winning and higher-valued rewards—have been also been used in the INSTANT (*11*), Steptacular (*12*) and Insinc (*13*) projects.

Friends. Participants were allowed to invite their friends (such as those who were eligible to participate in CAPRI) to join the program as well as to connect with their friends on the CAPRI portal. A participant could see their friends' recent updates; e.g., a status upgrade, a cash award won, etc. This feature provided a basis for social influence to spread.

"Magic Box". From the data it gathered, CAPRI learned a participant's preference for commuting off-peak (e.g., only twice a week, only on Monday and Tuesday mornings and Wednesday evenings). It also learned a participant's propensity for shifting to off-peak based on their response to past offers. Based on these learnings, CAPRI offered personalized incentives through a tab in a commuter's portal called *"Magic Box"*. Each week some of the participants received such offers. Magic Box offers were previously used in Insinc (*13*).

"Trendjacking". Stanford is involved in numerous high profile sporting events like the Rose Bowl, the "Big Game" (the annual football match between the Stanford Cardinals and the

Berkeley Golden Bears), etc. CAPRI offered tickets to some of these events and used them to incentivize behavior shift or increase enrollment.

The My Beats smartphone app and parking incentives. CAPRI detected walking and biking activity using the My Beats app (for both Android and iOS). The app was also developed so as to detect where a person parks so that we could reward those parked in designated and underutilized parking lots. However, due to poor cellular signals at some of the parking structures, My Beats could not accurately and reliably detect parking behaviors. Therefore, we could not implement the parking incentives portion of CAPRI.

4. ANALYSIS OF CAPRI

The CAPRI program started on April 2, 2012 and ended on September 30, 2014. Over the two and a half years, 4,057 Stanford affiliates completed the registration process; this includes 3,082 car commuters and 975 biking/walking commuters. These car commuters cover about 30.0% of the 10,290 car commuters in Stanford who were ever eligible to participate during this period. A graph of the number of registrations over time is shown in FIGURE 2. The figure indicates that there were significant increases in the number of registrations during promotional programs like the Rose Bowl Challenge and from personalized offers like the invite-a-friend magic box. These users conducted a total of 734,562 RFID scans and 98,751 My Beats trips. CAPRI has given out a total of $211,989 in incentives.

Demographics

A closer look at the demographics of CAPRI participants reveals that 63% are female; 72% are staff members, 14% are students and the rest are faculty; and 68% are younger than 45 years of age. On an average day, 795 unique participants make 1,196 automobile trips. Note that a unique participant can contribute both a morning and an evening trip. Moreover, the scanners do not operate other than during the 6 hours specified; thus, a participant's morning trip may not be detected even though their evening trip is detected. The My Beats app records 158 unique participants making a total of 225 walking or biking trips on an average weekday. 1,095 participants have at least one CAPRI friend and 46 users have six or more friends. The top friend-maker in CAPRI has 31 friends.

Automobile Commutes

In this section we investigate the behavior of automobile commuters in CAPRI. Stanford University employs an independent consultant company to count the number of vehicles entering and exiting campus each day for six weeks in the spring and two weeks in the fall each year. This generates the "cordon count data" and gives an aggregate profile of all the traffic entering and leaving the campus during the morning and evening peak and shoulder hours.

FIGURE 3 compares the profile of the overall Stanford traffic monitored in 2013 and traffic due to CAPRI users since the start of program. For the three-hour monitoring window of CAPRI in the morning and afternoon, i.e. 7–10AM and 4–7PM, we average over days and normalize the traffic time density so that the area under each curve in FIGURE 3 is exactly one. From the aggregate profile collected by the university, we find that during an average day a total of 11,620 inbound trips and 13,315 outbound trips occur in the corresponding monitoring windows (this includes pass-through traffic, visitors, construction vehicles, etc.). CAPRI commuters make 619 inbound trips and 577 outbound trips per day during the same hours. The percentage of the number of commutes before, during and after the peak hour is also shown in the figure. The fraction of trips in the gray-shaded area, indicating the peak hour, is the *peak-hour trip ratio*.

From FIGURE 3, we see that:

- **The overall Stanford traffic density is heaviest during the peak-hours**. The morning peak-hour trip ratio is 38.2% and the evening peak-hour trip ratio is 37.3%.
- **CAPRI users avoid peak hours.** For CAPRI participants, the peak-hour trip ratio is only 30.1% in the morning and 32.4% in the evening, which is a 21.2% and a 13.1% reduction from the Stanford-wide traffic.
- **CAPRI users respond to incentives**. The commute density for CAPRI participants peaks adjacent to (but just outside) the peak hours. Furthermore, CAPRI users prefer commuting during the hour before the peak hour as compared to the hour after the peak hour.

As only aggregate statistics about Stanford traffic are available from the cordon count, we cannot unambiguously determine whether there is a significant shift in the commute hours of CAPRI users after they joined program. It is possible that CAPRI users may have been commuting during off-peak hours even before the program. To support the hypothesis of a behavioral shift under incentives, we conducted a survey in May 2013, in which users were asked if they had shifted their commute time after joining CAPRI. In the next section, we compare the performance between self-declared shifters and non-shifters and gain some insight into their behavioral change.

Shift statistics segmented by user-declared behavior change

In May 2013, a survey of CAPRI participants was conducted. The survey aimed to obtain a better understanding of CAPRI participants' behavioral change, especially given the lack of commute data for these users before they joined CAPRI. The responses from the survey are used to determine if there has been a shift in the participant's commute times since joining CAPRI, the amount of shifting, the reason for shifting, etc. In total, exactly 1,000 CAPRI users responded, among which 602 users claimed that they had shifted commute time by some amount since joining CAPRI, while 398 users declared that they did not shift. Based on this information, we split the users into two groups: self-declared shifters and self-declared non-shifters.

As shown in FIGURE 4, self-declared shifters did indeed shift: the peaks of the time density of these commuters occur at 7:58 and 9:02 for morning inbound commutes, and at 16:58 and 18:01 for afternoon outbound commutes. These are times just adjacent to, but outside, the peak hours. The peaks of the commute time density for self-declared non-shifters occur well before peak hours: around 7:30 for morning inbound commutes, and 16:15 and 16:40 for afternoon outbound commutes, which are *drastically* different from the self-declared shifters. From these observations, we infer:

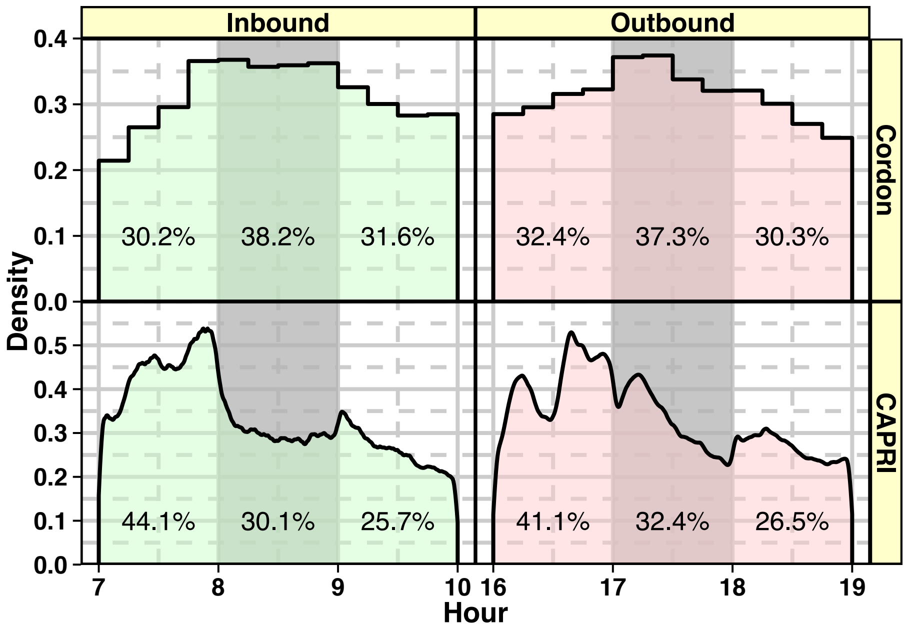

FIGURE 3 Stanford commute time density (cordon counts) vs. CAPRI participants' commute time density on an average day. The time window is 7–10AM and 4–7PM. Areas shaded gray indicate the designated peak hours: 8–9AM and 5–6PM. Each density is normalized: the area under each curve is 1.

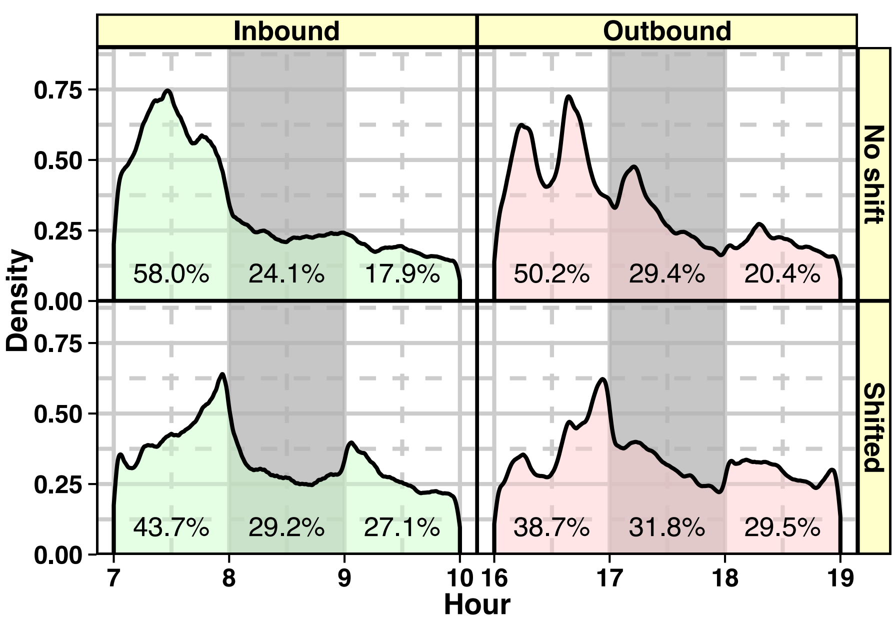

FIGURE 4 Commute time density for self-declared shifters and non-shifters in CAPRI survey. Areas shaded gray indicate the designated peak hours: 8–9AM and 5–6PM.

- The self-declared shifters shifted the *minimum amount necessary* to receive rewards from CAPRI; these shifts can be reasonably attributed to CAPRI.
- The self-declared non-shifters were likely already commuting *far away from peak hours*. Although CAPRI did not cause this commute behavior, it provides incentives for these users to *maintain* their behavior.

Linear regression on features affecting automobile commute time

To further examine the behavioral shift of CAPRI users, we conduct a linear regression analysis to quantify the effects of different factors that affect the commute times of CAPRI participants. The commute time of each participant on every morning/afternoon is regressed on:

- Whether the user has won any rewards from CAPRI in the past week;
- Whether the user has any friends winning rewards from CAPRI in the past week;
- Whether the day of the commute is a boost day for this user;
- The day of the week.

These features capture the impact from incentives, friends' winnings and daily schedules. As the peak hours in CAPRI are in the middle of the 3-hour windows (7AM–10AM and 4PM–7PM), commuters may shift their commute times *earlier* or *later*. To consider shifts in different directions, we categorize users into two groups: those whose median commute time is before the center of the peak hour (early users) and those whose median commute time is after the center of the peak hour (late users). Thus, for morning commutes, early users consist of those whose median commute time is prior to 8:30, while late users consist of those whose median commute time is after 8:30; for afternoon commutes, early users are those whose median commute time is prior to 17:30, and late users are those whose median commute time is after 17:30.

TABLE 1 shows the linear regression coefficients for different features affecting CAPRI participants' commute time. As shown in the table, for early users, winning rewards in the past week can have an immediate impact on their commute time: they shift 4 to 5 minutes earlier in both morning and afternoon commutes (hence away from peak hours). The winning of a participant's friend also has an impact, albeit a smaller one: early commuters who have friends winning rewards in the past week travel around 1.5 minutes earlier. Early commuters also advance their commutes by an additional minute on their boost days to ensure receiving bonus award points.

For late users, those who won rewards in the past week shift about 3 minutes later in morning and afternoon commutes (hence away from peak hours). Rewards won by friends and boost days do not significantly influence the afternoon commutes of late users.

On Fridays, both early and late users tend to leave earlier. In particular, late users leave 10.8 minutes earlier on Fridays.

In summary, the rewards in CAPRI have a direct effect on participants' commute time: they shift their commute time away from peak hours when receiving rewards in the recent past. The influence of friends and the boost day is also observed.

TABLE 1 Linear Regression Coefficients for Different Features on CAPRI Participants' Commute Time. Statistically Significant Coefficients Are Shown (5% Significance Level).

Morning Commutes	**Early Users**		**Late Users**	
	Time	**p-value**	**Time**	**p-value**
Mean commute time	7:50	$< 2\times10^{-16}$	9:01	$< 2\times10^{-16}$
The user won rewards in the past week	-5.3min	$< 2\times10^{-16}$	+3.2min	$< 2\times10^{-16}$
The user has friends who won rewards in the past week	-1.5min	3.51×10^{-10}	-	-
It is the user's boost day	-1.0min	3.41×10^{-7}	+1.6min	1.48×10^{-9}
It is Friday	+0.9min	7.02×10^{-4}	-2.3min	2.05×10^{-11}
Afternoon Commutes	Early Users		Late Users	
	Time	p-value	Time	p-value
Mean commute time	16:58	$< 2\times10^{-16}$	17:57	$< 2\times10^{-16}$
The user won rewards in the past week	-4.0min	$< 2\times10^{-16}$	+2.8min	1.18×10^{-13}
The user has friends who won rewards in the past week	-1.7min	5.00×10^{-9}	-	-
It is the user's boost day	-1.0min	4.10×10^{-5}	-	-
It is Friday	-3.0min	$< 2\times10^{-16}$	-10.8min	$< 2\times10^{-16}$

My Beats App Commutes

In My Beats, variable numbers of points are given for walking and biking commutes based on distance. Most of these trips are between 10 and 30 minutes in duration.

We observe that there are some My Beats app users who also have automobile commutes logged in CAPRI. Indeed, some users almost completely converted to walking and biking commutes after the launch of My Beats. To find these users, we define a *convert* as a participant who had at least 10 automobile commutes logged before the My Beats launch, has since logged more than 10 My Beats trips, and has more My Beats trips than automobile commutes since the launch. In total, there are *28* such converts. For example, there is a participant who made 192 automobile commutes before the launch but made *exclusively* bike commutes after the launch of the app. This shows that CAPRI is effective in persuading some participants to shift modes from driving to walking and biking.

"Magic Box" and Trendjacking

In total, CAPRI deployed more than 10 rounds of magic boxes offers in the fall of 2013. These included instant status upgrades, bonus points for friend invites, bonus points for eligible trips, and points for completing a survey on commute behavior.

Magic boxes are effective in shaping participants' commute behavior. For instance, in August 2013, CAPRI issued a one-week magic box that gives bonus points for eligible My Beats trips. 202 users accepted the offer. FIGURE 5 shows the number of My Beats trips made by CAPRI participants. As shown, those who accepted the offer increased the number of My Beats trips they made by 61% compared to the week before; whereas, other participants had an increase of only 1% in trip count over the previous week. Additionally, a memory-effect can be observed in those who accepted the offer: the two weeks following the end of the magic box saw increases of 36% and 47% in the number of My Beats trips over the week prior to the magic box.

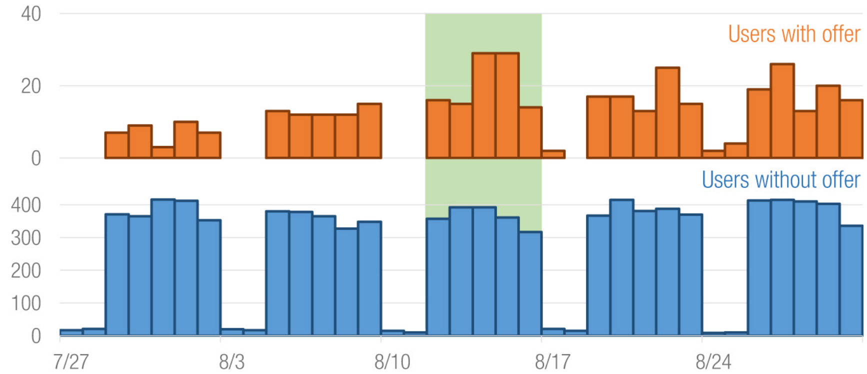

FIGURE 5 The number of My Beats trips made by CAPRI participants, grouped by whether the user received and accepted the magic box offer of bonus points for eligible trips. Shaded week indicates the bonus period.

During the 2013 Rose Bowl Challenge (an annual collegiate football championship for which Stanford qualified), CAPRI offered five pairs of tickets to some lucky participants. In order to qualify for the draw, a participant had to invite their friends to join CAPRI and each accepted invitation earned the participant one entry into the raffle. Over the 2 weeks period of the challenge, over 500 friend invitation emails were sent and 287 invited users successfully completed registration, resulting in an increase of over 13% in CAPRI's total user population.

5. SUMMARY

This paper analyzed CAPRI, an incentive program that aimed to shift drivers out of the peak hours and towards alternate modes such as walking and biking. We conducted an analysis of CAPRI based on 734,562 automobile trips and 98,751 walking and biking trips collected from 4,057 CAPRI participants during two and a half years. We found that the rewards in CAPRI were effective in incentivizing users to drive during off-peak hours, and to walk and bike. In particular, rewards received in the recent past shifted users' commute times away from the peak hours, and there were some users who converted from driving to walking or biking to work. Furthermore, personalized offers—the "magic box"—was useful in shaping users' commute behavior and increasing their participation.

As mentioned in the paper, the My Beats app could not detect parking behaviors accurately and reliably due to poor cellular coverage at some of the designated parking lots. In future, we intend to study parking incentives.

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