Behavior Insights for an Incentive-Based Active Demand Management Platform

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ABSTRACT

Most current Travel Demand Management (TDM) programs such as vanpooling, ridesharing, or transit focus on managing travel demand of specific groups of commuters but are limited in effectively managing demand for automobile drivers, who are unable or unwilling to participate in such programs.

This paper highlights results from a pilot field study conducted in a large west coast city experiencing major traffic congestion, and documents results of the use of an incentive-based active demand management (ADM) system focusing on automobile commuters. The system, called "Metropia," predicts future traffic conditions, applies a proprietary routing algorithm to find time-dependent shortest paths for different departure times, and, based on user request, provides automobile travelers with multiple departure times and route choices. Each of these travel choices are assigned points values, with higher points (and thus more valuable rewards) available for travelling during off-peak times and less congested routes, and lower points available for peak traffic travel times. The goal of this ADM system is to improve traffic flow and commuter travel times citywide, alleviating heavily congested areas without the use of new roadway construction by incentivizing travelers to change their travel behavior and avoid traffic congestion.

The level of rewards points available to users (commuters) by the system depends on the travelers' behavioral change degree and their contributions to traffic congestion alleviation. This system was implemented in Los Angeles, Calif., USA, as a small scale pilot field study carried out beginning April 2013 and lasting for 10 weeks. Results from this field study show the system is able to accurately predict travel time with Relative Mean Absolute Error (RMAE) as low as 15.20%. Significant travel behavior changes were observed which validate the concept of using incentives to influence people's travel behavior. Furthermore, field study results show 20% travel time can be saved for people who changed their travel behavior.

Key words: Active Demand Management (ADM), Travel Demand Management (TDM), Incentive, Departure Time Choice, Route Choice, Travel Behavior, Travel Time Prediction, Travel Time Savings

1. INTRODUCTION

Traffic congestion imposes a tremendous burden on society as a whole. For decades, the most widely applied remedy has been building more roads to better accommodate traffic demand, which turns out to be of limited effect: infrastructure construction and maintenance are very costly, and as more demand is induced, that added demand quickly saturates the newly built highways. Travel Demand Management (TDM) is another approach that has been receiving continual attention from both academic research and real-world practice, aiming to effectively influence people's travel demand, provide more travel options, and reduce the need for travel. A variety of TDM programs have been applied in real world practice, such as flexible work hours, teleworking, vanpooling, ridesharing, transit, etc.

Another aspect of TDM worth noting are travel pricing strategies, such as congestion pricing, HOV to HOT conversion, and parking pricing, which aim to influence travelers' behavioral changes by imposing monetary penalties on commuters. Although some of these strategies have proven to be, to a certain extent, effective in changing travelers' behavior while increasing revenue generation, this "stick" approach remains controversial on issues like socio-economic equity and capacity utilization efficiency.

Active Traffic and Demand Management (ATDM) - an increasingly popular strategy aiming to dynamically adjust network demand and supply in real time in order to improve operational efficiency - is surfacing as an viable approach for congestion management. In the realm of Active Demand Management, an opportunity that has not been fully explored in literature is to dynamically incentivize those auto drivers to make smarter travel choices such as departing outside peak periods or taking less congested routes to avoid traffic congestion.

Incentives are well known in TDM literature as well as in various behavior economics studies; however, incentives have not been attempted in influencing driver departure and route choices. Some previous pilot study research and practice advocated travelers to "avoid rush hour" or "use a transit mode" using incentives, and the results show that incentives are promising in altering a certain group's behavior [1, 2]. However, these studies did not provide predicted travel time information for different future departure times or alternative route options, without which travelers had limited information to assist their decision making and had to reply on the past experience. Another remaining question is how to develop a financially sustainable incentive program so that the program could be a market-driven, financially sustainable economics process.

In this paper, the development of an incentive-based active demand management system focusing on auto commuters[1] will be reviewed. The system, called "Metropia," predicts future traffic conditions, applies an advanced routing algorithm to produce the best route and future departure times, providing travelers with multiple departure time choices, with each choice associated with predicted travel time as well as its respective reward. The goal of this ADM system is to effectively alleviate traffic congestion in cities by incentivizing travelers to change their travel behavior and avoid traffic congestion. The level of rewards provided by the system depends on the travelers' behavioral change degree and the contribution to traffic congestion alleviation. The pilot field study results of such system in Los Angeles, Calif., USA, will be presented, with promising traveler behavior changes and travel time savings observed.

The rest of this paper will be organized as follows: Section 3 reviews the relevant past literature on Travel Demand Management and Pricing strategies; Sections 4 and 5 review the development of the Metropia system and the data collection mechanism, respectively; and Section 6 presents the pilot field study results in Los Angeles. Section 7 concludes this research and discusses future research directions.

2. LITERATURE REVIEW

Travel Demand Management is the application of strategies to reduce travel demand or redistribute this demand temporally or spatially [3]. Managing both the "growth of" and periodic "shifts in" traffic demand are necessary elements of managing traffic congestion. The performance of the transportation system will be adversely affected if traffic demand is not managed. Managing traffic demand today is about providing travelers, regardless of whether they drive alone, with different options [4].

Various strategies have been developed in the past to manage travel demand, and can be categorized as "soft" and "hard" measures (7, 8). The soft strategies usually refer to those that influence travelers' trip decision by providing traffic information through an advanced traveler information system (ATIS), educating people to reduce unnecessary trips or use transit instead, encouraging teleworking or teleconferencing, or reduce traffic by vanpooling or ridesharing, which encourage but do not enforce behavior change [5]. Some implementation case studies include the TELE-Bus in Krakow, Poland, which provides on-demand transit service, based on a Dynamic Dispatch and Routing platform, in order to attract new transit passengers and help build more effective bus fleet management. This study reported a 600% increase of the transit passengers after six months of pilot study [6]. The MITTENS (Messaging Infrastructure for Travel Time Estimates to a Network of Signs) program in San Francisco provides real-time freeway and CalTrans travel time information to motorists in order to induce en-route mode shifts; the internal algorithm is deployed to determine travel time by using available information and internal logic [7]. In San Francisco, the Predict-a-Trip[SM] was built based

[1]The incentive program can be easily extended to multiple modes, but auto-only mode is the principal interest of discussion in this paper.

on the popular 511 Driving Times^{SM} service by using historical information on freeway traffic speeds and driving times to provide point-to-point forecasts for about 90% of the Bay Area freeway network; travelers can access this info via the phone, web or freeway message signs. It is helpful for motorists to obtain route information not only for planning trips, but also for them to consider taking public transit instead of driving, or to use the ride-matching tool for prospective carpools [8]. Studies on using soft strategies to manage demand also include the dynamic ridesharing iOS application in Cork, Ireland [9]; the SmartRide program to track carpool, vanpool and transit use information for company employees internally [10]; the shuttle systems used to reduce driving in Zion National Park [11]; the transit-oriented development in the Hillsboro, Portland Metropolitan area in Oregon [12]; and so on.

The other type of strategies that use penalty to enforce travel behavior changes are called hard policy measures [13]. The most commonly seen examples of hard strategies are toll roads, congestion pricing and parking pricing. This type of strategy focuses on using the "stick" approach to induce the behavioral changes, but has been facing challenges in gaining public support, which could result in politically unfeasible measures [14, 15]. Road pricing has been argued by transport economists as one of the most efficient strategies to alleviate congestion externalities [16, 17], although the practice is controversial and its behavior implications are not well understood [2]. Implementation case studies of hard strategies include the variable Bridge Tolls used in Lee County, Fla., to manage traffic congestion and was able to spread traffic away from the peak period. Over the peak hours, the tolls on two principal bridges were raised from 75 cents to one dollar, and for the off-peak times a 50-cent discount was provided. With a $9.7 million grant from the Federal Highway Administration and another $7 million "emergency revenue reserve," 5% of traffic was shifted from peak to off-peak time periods, with as many as half of surveyed respondents indicating they always or sometimes considered the discounts prior to making a trip across one of the bridges [18]. Similar dynamic pricing strategies can also be found in Seattle, Los Angeles, San Diego, and Atlanta, where dynamic pricing of High Occupancy/Toll (HOT) lanes and incentives for High Occupancy Vehicle (HOV) usage are applied [19].

Recently, researchers have reversed the idea behind these measures and are using incentives to influence traveler behavior. The effectiveness of using rewards to reinforce a desirable behavior is supported by a large volume of empirical evidence [20, 21]; however, the implementation and relevant research on incentives in the transportation area have a relatively short history. An experiment with respect to 43 drivers was carried out during an eight-day temporary freeway closure in Osaka, Japan, where 23 travelers were offered a one-month free bus ticket, but the free ticket was not given to the other 20 drivers in a control group. The result shows that drivers who received a one-month free bus ticket in the experiment used the bus more frequently after the intervention. The increase was 20% higher than the frequency of bus use before, although it turns out in this experiment that these behavior changes are not permanent [22]. A longitudinal study in Germany investigated the effects of an intervention on increased bus use among college students by offering the incentive of a pre-paid bus ticket [23]. In Melbourne, Australia, an early bird ticket program was proposed to alleviate the rail overcrowding issue during peak hours. Free rail fares were provided for rail travelers completing their trips before 7:00 a.m. as incentives to shift demand from the peak to relieve the overcrowding problem [24]. In a 13-week field study conducted in The Netherlands, 340 participants were provided with daily rewards—monetary and in-kind --in the second half of 2006, in order to encourage them to avoid driving during the morning rush-hour [1, 2]. In the U.S., NuRide encourages people to drive less and travel by different modes, and it rewards such activities through a self-reporting mechanism [25]. Stanford University also used the idea of incentives to manage parking problems in Palo Alto, Calif, through Dynamic Parking Pricing [26]. The challenge of this program, however, is that it cannot distinguish the users who actually shifted from peak hours from those who were already accustomed to travel during the off-peak time periods.

The "carrot" approach of using incentives to influence travel behavior and manage travel demand is getting increasing attention, and could be used as an alternative or in tandem with existing "stick" approaches. Most past case studies did not offer predicted traffic condition information, so travelers had to rely on their experience or limited knowledge, which can be outdated to plan their trips, and which could make the benefit of such behavioral changes unpredictable. Most studies focusing on automobile commuters were also implemented onsite through small-scale studies. In this pilot field study, travelers are provided with predicted travel time and incentives information for different departure time choices and route choices, and they can use this information to assist their trip decision making and avoid traffic congestion.

3. METROPIA ADM PLATFORM

Metropia Mobile is a recently available mobile traffic app that uses prediction and coordinating technology combined with user rewards to incentivize drivers to balance the traffic load on the network, and reduce traffic congestion. Metropia uses advanced algorithms to determine which departure times and routes have available capacity, and offers varying levels of incentives for using less congested departure times and routes. Drivers use the app to reserve these faster routes, and when the recommended departure time gets close, the app reminds drivers when it's time to leave.

The Metropia system keeps track of the number of drivers using these alternative routes and times, and automatically adjusts incentive levels for recommended trips if too many Metropia drivers request to use the same alternate routes. As shown in Figure 1, Metropia servers use both real-time and historical data to analyze (in space and time) where available capacity exists, whereby moving additional demand that will lead to overall reduction of travel time and congestion (Step 1).

The Metropia server system then utilizes such information to estimate the amount of "trekpoints" to be awarded for each departure time and route. If a departure and route is found be more beneficial to the entire system, a higher amount of trekpoints are allocated to that departure time-route option. Metropia also provides predicted experienced travel time for future departure times. The accurate prediction[2] empowers a driver to decide to leave now or depart later, considering the onset of congestion. The

[2]Extensive field testing shows that the prediction error for Metropia is merely at 15%, much less compared to two other major navigation tools at 30% and 40% respectively.

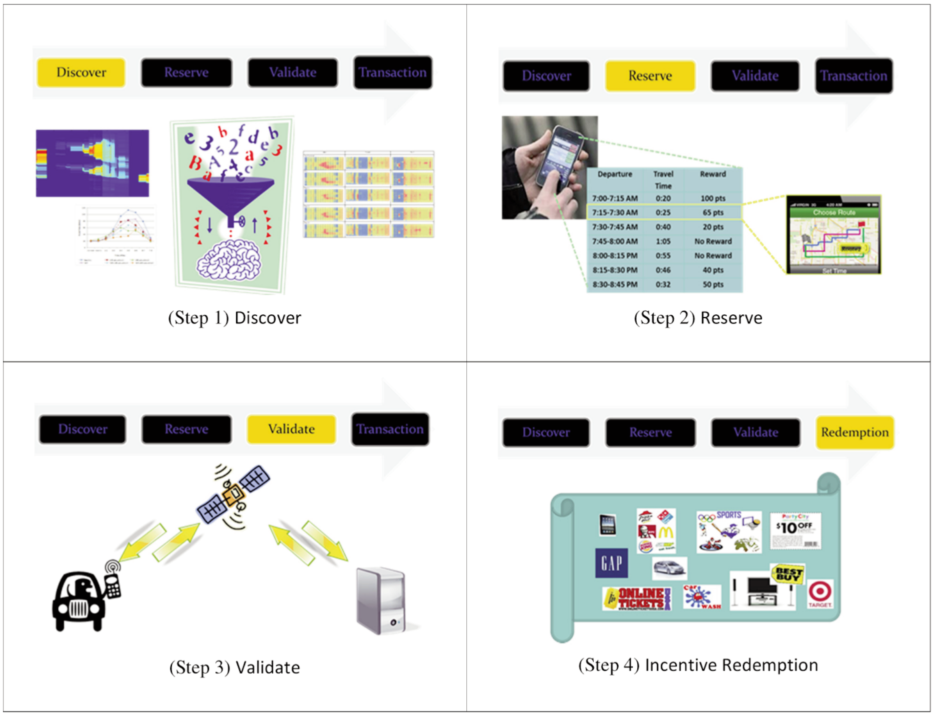

Figure 1. Metropia Mobile user experience

trekpoint incentive and travel time prediction is a combination to motivate drivers to use a less congested route and time. A driver will then make a reservation for a specific route and time (Step 2).

Ten minutes prior to the reserved departure time and route, the GPS will turn on and a message will pop up to remind the driver that it's time to leave. A certain time buffer is allowed so that the driver can leave within a certain time window. Once the trip is started, Metropia becomes a navigation app that provides audio turn-by-turn navigation guidance to help the user follow the reserved route until reaching the final destination (Step 3).

A user can continue Steps 2 and 3 in order to continue accumulating trekpoints. The earned trekpoints can then be redeemed for various discounted products and services, freebies, lotteries, or even donated to charities (Step 4).

4. PILOT FIELD STUDY PROCESS

4.1. Pilot Field Study Overview

The Metropia system uses a mobile app to give drivers the least congested routes and times to leave, and offers rewards to encourage drivers with the flexibility to avoid the most congested time and roadways. In this process, incentives are provided as an extrinsic motivation to encourage such behavior change. Besides this, and more importantly, the intrinsic motivation could be equally powerful to monetary incentives for the pilot field study testers to continue to use such an ADM system and reinforce their behavioral changes. This lies in the following two aspects:

1. Such system's capability to accurately predict the traffic condition ahead of time, so as to intelligently determine the shortest path from origin address to destination address.
2. Such system's travel time saving capability given that users are willing to change their travel behavior by either leaving at a different time, or changing the route they normally take, or changing both aspects.

The Metropia pilot field study was conducted beginning April 2013 in the city of Los Angeles, Calif. The main purposes of this 10-week pilot field study were to test the performance of such ADM system and to further validate demand management ideas and travel time saving performance.

For this pilot field study, 36 commuters were recruited in the city of Los Angeles to participate in the test. Twenty commuters were using Metropia Android app, and the remaining 16 commuters were using the Metropia iOS version of the app. It should be pointed out that both the Android and iOS versions of the app were using the same backend server in the Metropia ADM system, and were using the same dataset, so the behavior of both platform apps was the same.

Among all commuters that participated in the pilot field study, four were females and the rest males. Most had professional transportation backgrounds and commute to work daily, leaving home between 6 a.m. and 9 a.m. in the morning and leaving work between 3 p.m. and 6 p.m. Figure 2 illustrates departure time flexibility of the commuters according to a survey they completed when they signed up for the study. Their flexibility for leaving earlier in the morning is shown in (a), and for leaving later is shown in (b). The flexibility for leaving earlier or later in the afternoon commute trip is shown in (c) and (d), respectively. From Figure 2 we can observe that commuters tended to leave earlier for morning commutes, and they also had flexibility for leaving later in the afternoon for their trips home.

During the pilot study process, the Metropia team kept close communications with the study participants; a user feedback mechanism was designed and implemented to make sure feedback from commuters was collected in a timely manner. Each time a participant finished a trip, the Metropia system would automatically send a survey email to that commuter asking for feedback on the recently completed trip. In that survey email, additional information was also collected as immediate user feedback, including additional details regarding the specifics of the trip and the user's normal travel behavior without Metropia, for further analysis. More detailed information will be introduced in section 5.3.

As discussed above, the two main purposes of this pilot field study are to test the system travel time prediction accuracy and its capability to save travel time. The design of these two tests is presented in the following two sections.

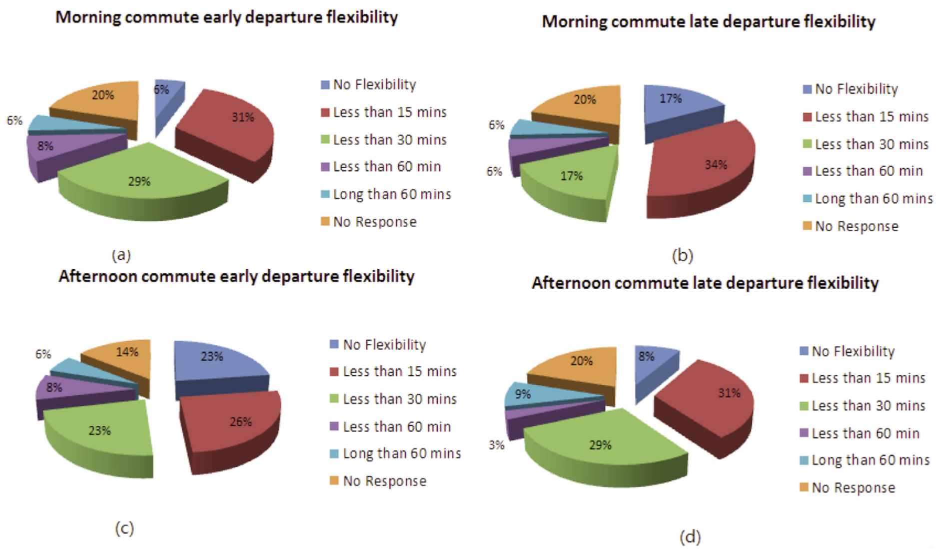

Figure 2. Pilot field study commuter departure time flexibility survey results

4.2. Accuracy Test Design

The capability to accurately predict traffic conditions is one of the key features to encourage travelers' participation in the ADM system. Metropia uses both real time traffic data and historical traffic information to predict traffic conditions in the future. The system is also fed with real time accident information, so that every time something unexpected happens to traffic flow, its traffic prediction system can take in such information and adjust prediction results in real time. Travelers using Metropia receive notification if they made a reservation but have not started the trip, which at that point they can reroute or reschedule. Users already enroute can be automatically rerouted before they encounter traffic congestion.

In order to validate system accuracy, two measurements were collected and compared:

1. Metropia predicted travel time. When users are planning for their trip, they can glance over the estimated route travel time for all available departure time choices and routes, and select the best choice that works for them. In order to get the incentives associated with that route choice, users are required to make a reservation, telling the system their decision, and Metropia backend server notes this reservation information, which includes the system predicted travel time for the route selected by the user as well.
2. Experienced route travel time. When the time comes and users need to start the trip, the Metropia system will push a notification to the users and remind them to leave, and the GPS module of their smartphone will be automatically enabled. The Metropia app will collect the user location information and speed data from the GPS and send it back to the Metropia backend server. The purpose of doing so is

to validate if the users finish their trip in a way consistent with their reservation, i.e. whether they left on time and traveled on the reserved route. Furthermore, the availability of such data allows us to know the start time and end time of the trips and calculate the experienced trip travel time, which is considered as the ground truth travel time.

It should be noted that not all GPS trajectory can be used in the accuracy test. The precondition of comparing Metropia predicted travel time with experienced travel time is both travel times are comparable, i.e. users should start from the same departure time and travel through the same road segments during the trip as they reserved, which are also the major validation criteria in Metropia system. A trip can only be validated if users leave within the departure time window and travel on the route the same way as they reserved, both dimensions shouldn't exceed the grace period that system allows. So, in this pilot study, only the validated user trips are selected as input data for the accuracy test purposes.

4.3. Travel Time Saving Analysis Design

Besides the monetary incentives that were used to encourage the behavioral changes, the intrinsic value of using ADM system comes from the travel time saving for the trips that users took. The purpose of travel time saving analysis is not only to prove the performance and travel time reduction capability of such system, but also to serve as instant feedback to the users, informing their achievement in travel time reduction and further encouraging such beneficial behavioral changes.

In order to quantitatively measure travel time savings, the following data needs to be collected:

1. Experienced route travel time. Same as data collected in section 5.2.
2. Original travel time. The time that users would have experienced if they left at their normal departure time and taken their normal route, or, in other words, the travel time they would have experienced without behavioral changes. The purpose of collecting such data is to use it as benchmark which by comparing with their experienced route travel time, the benefit from travel time savings of their behavioral changes can be quantified.

As described in section 5.1, each time a tester finished a trip, a survey email was automatically generated and sent to him/her asking for feedback of the newly finished trip. In that survey email, besides the user feedback, additional information was also collected regarding this trip and user's normal travel behavior without Metropia for further analysis. Users were first asked whether this was a regular trip, i.e. if this was a recurring trip that they usually traveled. They were then asked if they changed their usual departure time and route, and what their typical travel time was, in their experience. If this was an adhoc trip that users were not familiar, they would be asked if they would take the same route and leave at the same time without the information provided by Metropia, and their estimated travel time from origin to destination. Such surveys would help gain an understanding of the behavioral change degree of the users original travel time, which can be used to compute travel time saving.

With information about the traveler's original travel behavior, combined with the actual trip decision made by the user, the behavior changes for each individual traveler can also be analyzed –Did the user change his/her route? Did he or she leave at a different time, if so, by how much? The behavioral changes collected are analyzed in the following section.

5. PILOT TEST RESULTS REVIEW

The 10 week pilot field study was conducted from April to July 2013. In total, 687 reservations were made and 308 of them were finished.

5.1. Accuracy Test Result

The validated trip data were preprocessed before being used in the accuracy test to filter out some data that are not suitable for analysis. Observed noises that were filtered include:

1. Users engaged in mid-way activities, such as dropping off kids or picking up a coffee, which caused an obvious delay in his or her trip.
2. Post-trip travel, which for certain reasons, after users arrives at the destination, the GPS was not turned off and users continued to travel within the neighborhood.

These noises with abnormal travel time deviations can be found once the anonymous users' trajectory was plotted on GIS software and dense GPS points were observed. After preprocessing the data, the estimated travel time by Metropia (prediction) and user experienced travel time (Ground Truth) can be compared and the result is shown in Figure 3, in which the black bars denoting prediction are very close to the red bars describing ground truth. It indicates the system predicted travel time is very close to the user experience travel time.

The Relative Mean Absolute Error (RMAE) was also computed to evaluate the system accuracy changes over the 10 weeks, RMAE is calculated as below, where pred stands for predicted travel time and GT is the actual travel time following the route during the field testing

$$\text{RMae} = \frac{1}{\text{n}}\sum\left|\frac{pred - GT}{GT}\right|$$

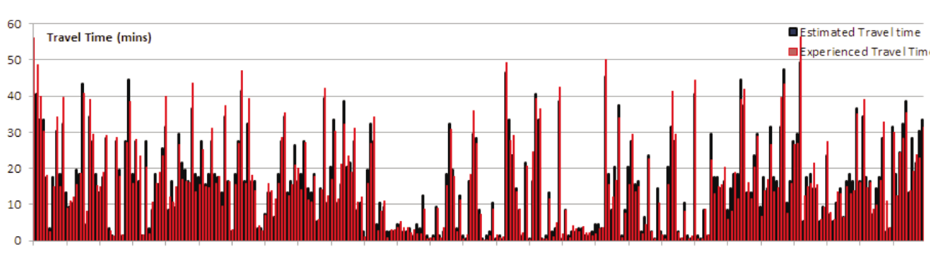

Figure 3. Travel time comparison between prediction and Ground Truth

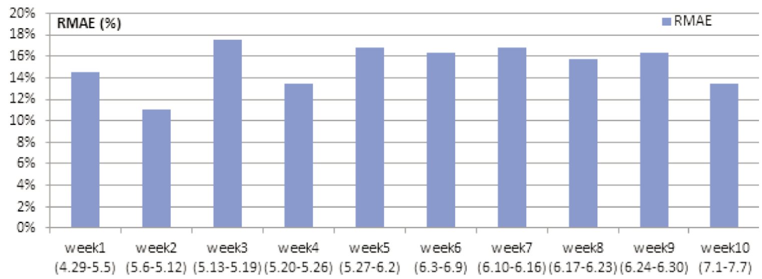

Figure 4. RMAE of travel time across the pilot field study period

Figure 4 shows the temporal changes of RMAE across the pilot field study period, from which we can observe the weekly average system error varied between 10% and 18%. During the field testing, the predicted travel time from the other applications were also recorded for reference purpose. For the entire pilot field study period, the overall RMAE was 15.20% which was much lower when compared to two other major navigation tools in the markets (around 30% and 40% respectively).

5.2. User Behavior Change

The key to a successful ADM system is to effectively influence people's travel behavior changes through available traffic management or demand management strategies, with an end goal of improved system efficiency with abetter balanced travel demand and network supply, fully utilizing existing infrastructure and alleviating traffic congestion.

The degree of user behavioral changes can be analyzed by comparing the user's actual trip decision with their normal travel behavior, without help from ADM platform. The user's actual trip making information is recorded and stored in the backend server, and his/her habitual travel behavior is collected from the daily email survey. The behavioral change results from the pilot test are promising, showing for all trips finished during this period using the provided ADM platform:

- Users chose to leave at a different time for as much as 60% of their trips;
- For 51% of their trips, users took a different route which was not the one that they were used to travelling; and
- Travelers changed both departure time and route choice for 35% of the trips.

Figure 5 shows user departure time shift distribution in the pilot field study. It can be observed that around 40% trips departed at the same time, indicating users either not having the flexibility in their departure time choice or simply unable to move. About 50% changed their departure time by 15 minutes, and other 10% of users had more flexibility in their departure time choice. The stats show more than 60% of users were willing to change their departure time, a promising result for the case of using incentives to encourage people to change their behavior.

It was quite encouraging to find out 35% travelers are willing to change both departure time and route choice with the incentives offered in this pilot study in Los Angeles. On the other hand, based on the author's other relevant research projects

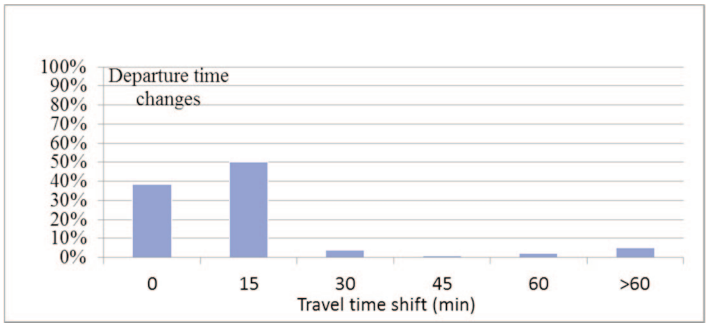

Figure 5. Departure time shift distribution in the pilot field study

[27, 28], it is also encouraging to find out that, with merely 10% drivers willing to change travel behavior, the traffic condition for the whole network can be alleviated significantly, and with 20% drivers cooperating and making better travel choices, most traffic congestion observed will disappear. Those analysis results clearly demonstrate the potentials of applying the proposed incentive-based ATDM strategy to reduce traffic congestions in the cities.

5.3. Travel Time Saving Analysis

As discussed in section 5.3, the intrinsic value of using the ADM system comes from the travel time saving of the trips that users took, which is another benefit travelers can get besides the monetary incentives used to encourage behavioral changes, and could be more powerful than the extrinsic motivation.

By comparing the ground truth travel time, which is the time experienced by the traveler using Metropia, and their original travel time, which is the time they would have experienced if they had left at their normal departure time without Metropia, the travel time saving for each route could then be computed. Figure 6 shows the relative travel time saving by week 10 of the pilot field study. The blue color stands for the relative average travel saving for all validated trips using the Metropia app, and red color is the travel time saving for the trips that travelers changed both departure time choice and route choice. It can be observed that travel time saving is generally 10% to 40%, and by changing both departure time and route choice, travelers can get more travel time saving than those who did not.

Analysis of the travel time comparison also reveals:

- In the pilot field study period, travelers who changed their departure time only, but stayed on the same route, can reduce their own travel time by19.40% on average
- People who changed their route only but their departure time can reduce their own travel time by10.0%
- People who changed both departure time and route choice can increase saved travel time by 20.12%
- People who left earlier than they used to can save travel time by 22.13%

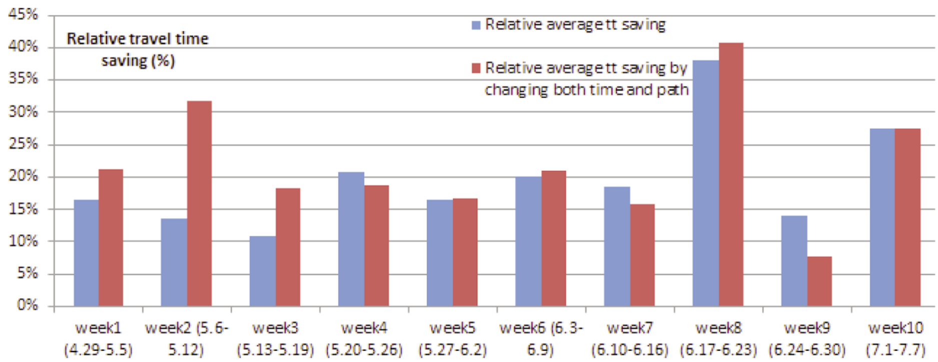

Figure 6. Weekly relative average travel time saving

- People who left later than they used to can save travel time by 19.32%
- The commute trips made in the morning can save travel time by 20.58 %
- The commute trips made in the afternoon can save travel time by 16.87%

The data analysis results show travelers were able to save travel time not only by shifting their departure time, which is straightforward as they avoided peak hour congestion, but also by taking alternative routes. Theoretical research usually assumes all travelers have complete information about the whole network structure and traffic condition, so that everyone can travel on the shortest path in the network, which does not necessary hold in reality. As a matter of fact, sometimes unbalanced traffic can be observed, where a freeway is completely jammed but the arterial is still under light traffic condition. The capability of such system being able to intelligently detect traffic flow changes and route users to utilize the underused road is essential to better balance the need to travel a particular route at a particular time, using the capacity of available facilities to handle the demand efficiently.

It can also be observed that temporally shifting departure time is able to save more travel time than spatially changing the route to take. Furthermore, if travelers are flexible in both departure time and route choice, they can save more travel time by changing both.

6. CONCLUDING REMARKS

This paper documents the pilot case study process and the results of an incentive-based active demand management system focusing on automobile commuters. The system, called "Metropia," predicts future traffic conditions using both historical and real time traffic data, applies a routing algorithm to find time dependent shortest paths for different departure times that a user requests, and, in the end, provides travelers with multiple departure time choices, with each choice associated with different predicted travel time as well as varying rewards. The goal of this ADM system is to effectively alleviate traffic congestion in cities, and such goal is achieved by providing different levels of incentives to travelers to encourage them change their travel behavior and avoid congestion. The level of rewards provided by the system depends on the travelers' behavioral change degree and their contribution to the traffic congestion alleviation.

Such a system was implemented in Los Angeles, Calif.. A pilot field study was carried out beginning in April 2013 and 10-week results are reported. The result of this field study shows the system is able to accurately predict travel time with RMAE as low as 15.20%, outperforming two major navigation apps in the market. Significant travel behavior changes were observed: users were found to be willing to change both departure time and route choice for as many as 35% of their trips, which validates the concept of using incentives to influence people's travel behavior. Finally, the field study result shows 20% travel time can be saved for people who changed their travel behavior.

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