INSINC: A Platform for Managing Peak Demand in Public Transit

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Abstract

Public transit systems in several cities experience peak hour overloads. As a result vehicles are crowded, often to the extent that commuters cannot board them. It is very expensive or even impossible to further increase peak capacity; peak demand must be actively managed. This article describes INSINC, a project that manages peak demand by incentivizing commuters to travel off-peak. It uses random (raffle-like) rewards, social influence (commuters are compared to their friends), and personalized offers to manage peak demand. A before-and-after analysis of participants' trips shows that INSINC cost-effectively induces commuters to shift from peak to off-peak travel times.

Introduction

Urbanization—the rapid growth in the population of cities—is straining transportation systems around the world. Traffic snarls on roads are resulting in a significant wastage of time and fuel, causing massive pollution, and increasing traffic accidents. To mitigate these problems, it is necessary to have widespread adoption of public transport. Fortunately, commuters in most cities do use public transport systems. But this very adoption and growing commuter bases are causing severe peak hour crowding in public transport vehicles. Peak hour commuters are occasionally unable to board vehicles and incur large delays while waiting for trains or buses they can board.

Public transport systems pursue two strategies to address peak demand: (i) increase peak supply, and (ii) shift demand to off-peak shoulder times. Increasing supply at peak times can be prohibitively expensive and prove inadequate, since it invites more off-peak load to shift into the peak. Further, there is a limit to which peak supply can be increased without violating inter-vehicle spacing requirements. For these reasons, public transport systems are increasingly exploring demand management strategies such as differential pricing and incentives.

This paper describes INSINC, an incentive scheme we have devised to shift demand from peak to off-peak shoulder times in Singapore's public transit system. INSINC was launched in January 2012 as a six-month trial and extended for a further 18 months, until December 2013. We describe the scheme, its main features, and its effectiveness in shifting peak demand. Due to space limitations, we are only able to present an overview that highlights the main findings and restrict focus to the first six months of the deployment.

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We shall explore details—statistical, behavioral and systemic—in further work.

A large conclusion of our work is that it is possible to shift peak demand with relatively modest amounts of incentive money. Three major aspects of the INSINC platform make this possible: (a) random (raffle-like) rewards, (b) social influence — the positive effects on a commuter of her/his friends in the INSINC platform, and (c) personalized offers.

Commuting data reveals that over 76% of morning peak trips are due to just 20% of commuters; by targeting these commuters with bonus offers for off-peak trips we are able to reward cost-effectively. Before-and-after comparisons of commuters in INSINC are used to understand the propensity and the extent of shifts from the peak hour. The data also reveal the difference in the shifting behavior of short and long distance commuters, those who redeem deterministically (at a fixed exchange rate) versus those who redeem randomly, etc.

Solving the Problem of Traffic Congestion

Transport planners are well aware of the need to manage both public transport supply (e.g., number of buses, trains) and demand (e.g., commuters) in concert. As long-term demand increases, supply needs to increase to keep pace. For transient peak demand it can be very expensive to add supply and, should supply be increased, latent demand moves in to fill it. Transport planners, therefore, understand that peak demand must be actively managed. They do so using one of three main strategies: (1) Quotas or rations: For example, Singapore limits the total supply of cars and Beijing forbids vehicles on roads on certain days depending on license plate numbers. (2) Prices: The Washington DC, Seattle and other public transit systems levy a peak hour surcharge. London, Singapore and Stockholm levy a congestion charge on peak time drivers. (3) Inconvenience: Certain modes or times of travel are made inconvenient; for example, Copenhagen limits parking spaces to curb cars and cities in the U.S. employ peak hour carpool lanes. However, these approaches are fraught with the danger of causing unhappiness amongst commuters.

Using Incentives - The INSINC Concept

Incentives are viewed positively because commuters are not penalized for undesirable behavior but rewarded for beneficial behavior. Incentives can be deployed incrementally, whereas, for reasons of equity, penalty-based methods have to include everyone from the start.

INSINC builds upon the INSTANT (Merugu et al 2009) and Steptacular (Gomes et al 2012) incentive programs; its design is based on the following principles:

a) Some commuters will respond to incentives by shifting their travel from peak to off-peak. Reducing peak trips by 10% will lead to a significant reduction in congestion measures.

b) Commuters respond more to "higher payout raffles" than to "lower payouts" made with certainty (i.e., people prefer a 1 in 100 chance of winning $10 than a $0.10 certain reward).

c) Social motivation—provided by friends, family and peers, and socially meaningful measures such as status—can amplify the effects of monetary rewards.

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Over a period of time, INSINC can learn a commuter's preference and propensity for exhibiting a particular behavior and personalize offers so as to obtain the best overall behavior in a cost-efficient way. We shall see more about such a "learn and customize" approach later.

How INSINC Works

INSINC is best described as a frequent commuter program, similar to an airline miles program. Its goals are to shift commuters from peak to off-peak trains and engender loyalty to the public transit system.

Signing Up, Winning Rewards, Inviting Friends.

A commuter registers and sets up his INSINC account using the unique identification number of his travel card. A weekday trip of Xkms earns X credits, and if the trip was initiated in the off-peak shoulder hours (6.30—7.29am or 8.30—9.30am), it earns 3X credits. The credits earned by a commuter are redeemable either at a fixed exchange rate (1000 credits = SG$1), or for prizes ranging from $1 to $100 in a fun online game — essentially a "self-administered raffle". Around 87.6% of INSINC participants preferred the raffle option, bearing out the general preference people exhibit for raffles over certain payments, especially when such payments are small.

There is a strong social element in INSINC. Participants may invite their friends from social networks and email services (Facebook, Gmail, Yahoo! mail, etc.), and they earn bonus credits when their friends sign up. Friends are displayed on a participant's INSINC page in a "ranking list" style: off- peak commuting friends on top, followed by others. A sample homepage is shown with the names redacted *(Figure 1)*.

Personalized Recommendations via the Magic Box.

Every Friday at 10am Singapore time, commuters receive a "magic box offer", which is an offer of extra rewards should they achieve behavior targets the following week. For example, a commuter traveling consistently in the peak hour may receive extra credits for off-peak travel the following week, while a different commuter may earn extra credits for inviting friends, and a new participant may get extra credits for learning some "INSINC facts". Personalized offers allow administrators to understand a participant's utility function: i.e., a commuter's willingness to exhibit a particular behavior, measured in monetary terms.

Figure 1. INSINC Homepage

INSINC Timeline

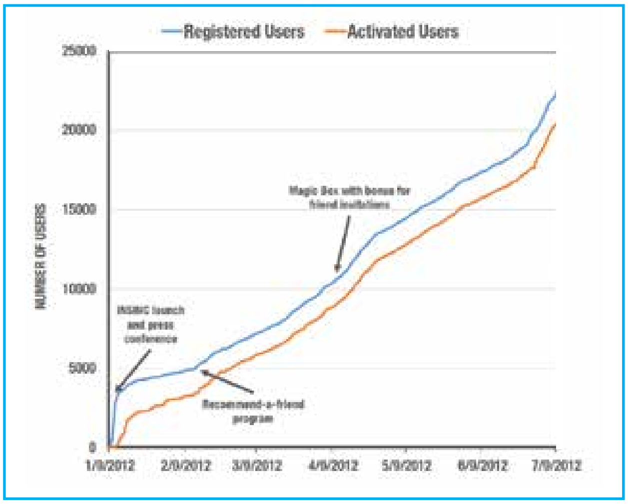
INSINC was launched on 10 January 2012 as a six-month research pilot by Stanford University and the National University of Singapore with the aim of shifting the travel patterns of Singapore's MRT morning peak hour commuters to off-peak times using incentives—monetary and social. At the end of six months, there were 22,867 registered participants of whom 20,319 were admitted. INSINC enjoyed a high word-of-mouth recruitment: 98,834 emails were sent by participants inviting their friends to join and 12,163 (62.1% of those admitted) had friends. A total of SG$137,639 was paid out as reward money, including both behavior incentive money (at the rate of SG$0.30 per commuter per week, on average), and sign-up and friend recommendation bonuses. The latter were made in the form of INSINC credits, equivalent to SG$1.50 per sign-up.

Figure 2 shows the enrollment in INSINC since its launch, highlighting some of the main features introduced to boost enrollment rate. The launch of INSINC in January 2012 brought in about 3,800 participants. However, because the initial "admissions" process consisted of two steps, an "application" step and an "activation" step, close to 1,000 applicants who were admitted did not come back for activation. Therefore, we revised the application process to consist of just one step. Chinese New Year, in the third week of January, sent commuters in holiday mode and this resulted in steeply declining enrollment between 22 January and 10 February 2012.

Recommend-a-Friend

In the second week of February 2012 we made it simpler for users to recommend friends and family by introducing Facebook, Gmail and Yahoo! Connect to INSINC. Launched on 14 February 2012, this feature immediately increased enrollment. We used the mailing lists of the travel card companies to mail INSINC

Figure 2. Enrollment in INSINC since its Launch



flyers to a few thousand commuters, and handed out flyers at train stations. While these latter efforts brought in several new users, the recommend-a-friend program has brought the most new participants. The enrollment rate picked up further when the Magic Box feature was launched on 13 April 2012.

INSINC Behavior Shifts Performance

In this section we present a series of before-and-after comparisons of peak to off-peak shifts in the INSINC commuting population. This is done across various "commuter segments". Thus, for each segment, we compare the percentage of peak vs off-peak trips[1] before a commuter joined INSINC to the same percentage after they joined INSINC. It is important to point out that not all commuters have the same length of historical records; indeed, the length of the records is highly variable and in future work we will give weightage to historical records appropriately so as

Social motivation—provided by friends, family and peers, and socially meaningful measures such as status—can amplify the effects of monetary rewards.

to remove biases. Since the number of records and commuters is large enough, the numbers we get by taking the records as-is give a statistically accurate number for the percentage shift in peak trips.

Definition of "Peak-Shift"

Suppose we wish to determine the shift from peak to off-peak hours in a group of N commuters. The dissimilar number of trips in commuter logs over a duration of time makes it necessary to compare shifts in terms of percentages rather than as raw numbers.

Let T_b be the total number of trips made by the N commuters during 5am to 12pm in the three months before they joined INSINC. Of these, let P_b be the number of peak trips made by the N commuters. Then $B=P_b/T_b$ equals the percentage of peak trips made by the N commuters before joining INSINC. Similarly, let T_a and P_a be the total number of trips and the total number of peak trips made by the N commuters after joining INSINC and until the date of analysis. Then $A=P_a/T_a$ equals the percentage of peak trips made by the N commuters after joining INSINC.

Peak-shift is defined as the quantity 100(A-B)/B*

For example, if P_b = 53,882, Tb = 145,224, P_a = 38,191, and T_a = 111,048, then B = 37.1% and A = 34.4%. This makes peak-shift = -7.3%.

Behavior Shift Comparisons

Figure 3 shows the probability density function of the commute start time for the hours 5am—12pm before (blue line) and after (orange line) commuters joined INSINC. There are four graphs indicating the shift for: (i) all commuters, commuters whose historical records had at least (ii) five peak trips, (iii) 10 peak trips, and (iv) 20 peak trips, respectively. One expects bigger shifts from those who've made more peak trips historically (since they have more to shift). On the other hand, those who were historically heavy peak-time travelers will likely shift less since they have a stronger preference for peak-time travel[2].

Figure 3 shows that the percentage shift in trips from peak to off-peak hours for all commuters was 7.49%. This includes many commuters who were traveling primarily in the off-peak hour before joining INSINC. Trips due to commuters who made at least five peak trips before they joined INSINC shifted by 10.1%. It is notable that this group contributed over 95% of peak trips made by all INSINC participants even though they were only 36% of the participants. *Table 1* summarizes the behavior shifts for different groups of commuters. There are other interesting commuter groups whose shifts are interesting to consider (e.g., gender- and age-based groups), but, due to a shortage of space, we will present them in future publications.

Figure 3 and *Table 1* allow us to conclude the following:

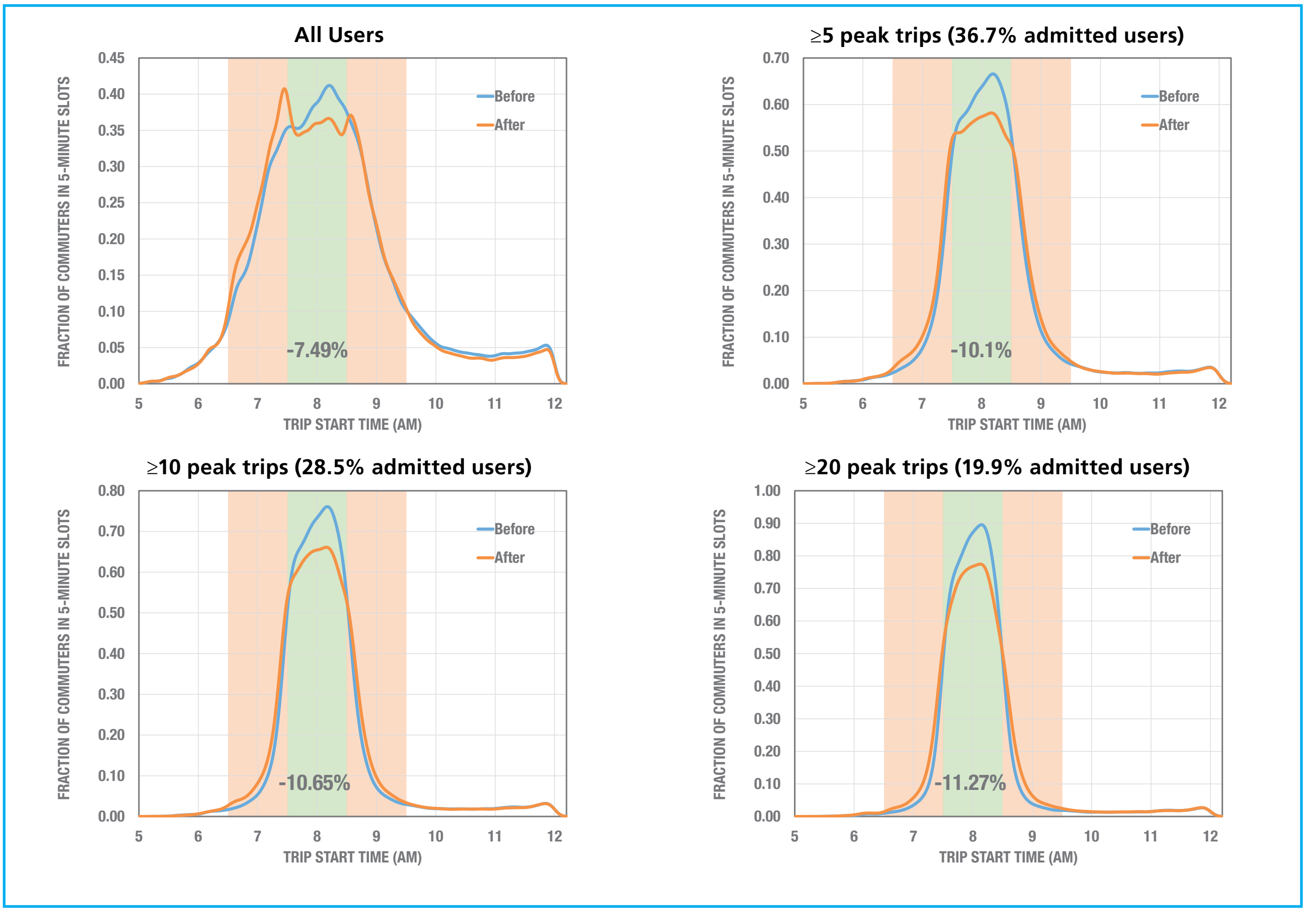
1. While the overall shift in the percentage of peak trips was 7.49%, among those who had made peak trips before joining INSINC the shift was in excess of 10%.

2. Those with friends (62.1% of admitted participants) perform significantly better than those without friends in INSINC. This was especially true in the "overall" category, which includes a substantial number of frequent off-peak travelers.

3. Those who played the game shifted more than those who don't. Note that the number of deterministic redeemers was just over 12% of the overall commuting population.

4. Short distance commuters in the "overall"

Figure 3. Probability Density Functions of the Commute Start Time



category performed poorly; however, when it came to those who historically traveled in the peak, the shift continued to be fairly strong. Given that short distance commuters have more opportunity to shift (for instance, they can shift to after the morning peak without being late at work), we believe Magic Box offers can induce a fairly strong shift in this group.

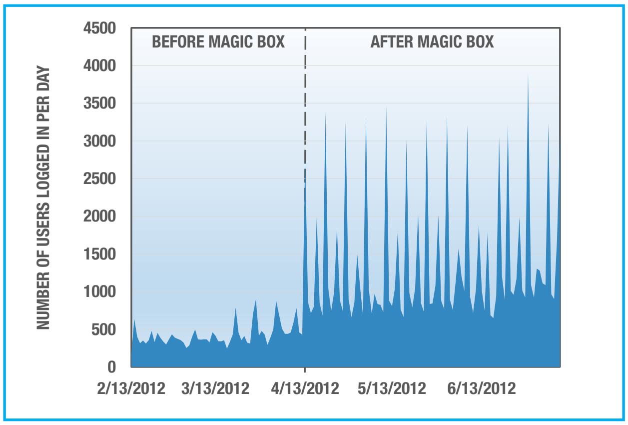
Table 1. Behavior Shifts for Different Groups of Commuters

Type of participants	Shift in percentage peak trips			
	All	>= 5 peak Trips	>= 10 peak Trips	>= 20 peak Trips
Overall	-7.49	-10.10	-10.65	-11.27
Those with INSINC friends	-9.70	-10.61	-11.14	-11.41
Those without INSINC friends	-3.70	-9.00	-9.69	-10.75
Those who play the game (random redeemers)	-8.41	-10.79	-10.92	-11.32
Deterministic redeemers	-5.07	-10.24	-10.96	-12.13
Short distance commuters [3]	-4.96	-10.49	-10.83	-11.88
Long distance commuters	-9.13	-9.77	-10.51	-10.81

Magic Box Effects

As described previously, Magic Box offers were extended to all participants on Friday morning each week, starting on 13 April 2012. The Magic Box had a significant effect in terms of increasing engagement with the INSINC site, as desired. Specifically, the number of INSINC participants visiting the site on a weekly basis increased from 27.2% before Magic Box was introduced to 39.7% after Magic Box was introduced, an increase of 45.8%. Further, commuters who opened the Magic Box once were quite likely to return and open it again. *Figure 4* shows the increase in engagement on a daily basis after the launch of the Magic Box on 13 April.

Figure 4. Increase in Engagement after the Launch of the Magic Box



Magic Box Performance Shift

We consider participants who had been admitted to INSINC before the launch of Magic Box. The number of such commuters was 45.9% of all admitted users. We found that the overall peak-shift in the month before Magic Box was launched equaled 7.46%, whereas in the month after Magic Box the peak-shift was 9.34%. Thus, the Magic Box was an effective tool in terms of increasing peak-shift.

Conclusion

The "holy grail" of demand management is the ability to shape the habits of commuters. INSINC aims to achieve this with stimuli that are social (friends) and personalized (Magic Box) to build intrinsic motivation in commuters and not rely solely on extrinsic motivation (monetary rewards). Intrinsic motivation is more desirable because it is self-sustaining but extrinsic motivation is salient and can be applied to overcome inertia—i.e., to get the ball rolling.

Any incentive mechanism suffers from "adverse selection": commuters most likely to sign up are those already traveling in the shoulder hours. Such commuters obtain rewards without providing peak shifts. However, committed off-peak travelers in INSINC played crucial roles: (i) they invited more friends to join, and (ii) since their commuting behavior was exemplary, their peak-hour friends shifted even more.

Habits take time to form: participants who had been in INSINC for less than two weeks hardly shifted. It took more than four weeks to get a consistent shift of over 7% shift from peak hours.

Engagement is key to maintain. Commuters who were disengaged with INSINC (i.e., very rarely visited the website) performed poorly. While the Magic Box significantly increased engagement, we learnt the following important lessons: (i) Keep communication simple: A clear and simple language is most effective, videos of key steps (e.g., receiving the reward money from the "top up" machine) are crucial, and it is better to offer sophisticated interventions involving multiple steps or friends to the initiated. (ii) Reduce friction: Seen from the commuter's perspective, INSINC is, first and foremost, an online service complementing the transit system. It is a service whose goodness will be assessed in terms of its "user friendliness", its "lack of friction", and its "cheerful responsiveness" to queries.

We must strive to produce an attractive and easy-to-use web service; ensure that the sign-up, data and payment processes are frictionless; and strive to respond to commuters' queries and complaints promptly and cheerfully.

As a final remark, INSINC has been extended for a further 18 months (July 2012 to December 2013) after the initial six months described in this paper. There is a wealth of data from this extended period which we expect will yield additional insights.

Acknowledgments

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Notes

[1] Recall peak hours are 7.30—8.29am, off-peak shoulder hours are: 6.30—7.29am and 8.30—9.30am. Most of the shift from the peak hour is to the shoulder hours.

[2] As there were about 2,000 participants who registered during 1st – 10th July whose behavior shift was not meaningful to consider, we only look at the behavior of participants who registered before 1st July.

[3] Short distance commuters are defined as those whose average trip length before joining INSINC was less than the historical mean trip length, equal to 13.2km.

References

Gomes, N.; D. Merugu, G. O'Brien, C. Mandayam, T. Yue, B. Atikoglu, A. Albert, N. Fukumoto, H. Liu, B. Prabhakar, D. Wischik. 2012. "Steptacular: An Incentive Mechanism for Promoting Wellness," NetHealth, Comsnets Workshop on Networked Healthcare Technology, January 2012.

Merugu, D.; B. Prabhakar, N.S. Rama. 2009. "An Incentive Mechanism for Decongesting the Roads: A Pilot Program in Bangalore," NetEcon, ACM Workshop on the Economics of Networked Systems, July 2009.

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