An Incentive Mechanism for Decongesting the Roads: A Pilot Program in Bangalore

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ABSTRACT

We describe an experiment conducted in Bangalore, India, for incentivizing a population of commuters to travel at less congested times. The goals were to reduce the travel times and increase the travel comfort of commuters, and to reduce congestion, fuel consumption and pollution. The project, called INSTANT (for the Infosys-Stanford Traffic project), ran for six months from Oct 6, 2008, to April 10, 2009 and incentivized the employees of Infosys Technologies, Bangalore. We describe the background, the incentive mechanism and the results. The INSTANT project involved about 14,000 commuters and succeeded in incentivizing many commuters to travel at uncongested times, thereby significantly reducing their commute times.

Our approach of providing incentives to decongestors contrasts with the current practice of charging congestors. It also contrasts with prior work on "selfish routing" which focusses on the reaction of commuters to a spatial choice of routes (same time, different routes) as opposed to a temporal choice (same route, different times).

Categories and Subject Descriptors

J.4 [**Social and Behavioral Sciences**]: Economics

General Terms

Algorithms, Economics, Experimentation

Keywords

Transportation networks, Road congestion, Selfish routing, Congestion charging, Incentive mechanisms

1. INTRODUCTION

The paper describes an incentive mechanism deployed over a six month period in Bangalore, India, for encouraging commuters to travel at off-peak hours. The experiment aimed to reduce the commute time and increase the travel comfort of the commuters, and to reduce congestion-related costs such as pollution and fuel. From a research point of view, the experiment provides a platform for testing ideas and hypotheses about charging schemes and incentive mechanisms related to congestion reduction. We articulate various hypotheses about commuter behavior, contrast monetary (positive) behavior incentives and congestion charging, discuss methods that are incrementally deployable and scalable. However, we view these articulations as a preliminary expression of our understanding. Further experimentation is necessary for a more thorough understanding and for enabling larger deployments.

Background. Road traffic congestion is a serious issue in many cities around the world. It has worsened considerably in the past few years, causing an enormous wastage of time and fuel. For example, a study [15] of several urban areas in the U.S. reports that in 2005 an estimated 4.2 billion hours of time and 2.9 billion gallons of fuel were wasted due to congestion. This amounts to a total loss of about $78.2 billion, up from $73.1 billion in 2004. See [1, 5] for other reports of the effects of congestion in the U.S. In urban areas, increased vehicular traffic has also led to severe pollution and parking problems.

For an exposition of the extent and nature of the problems in Bangalore, see [11, 12]. As noted in [12], the Information Technology boom in Bangalore over the last 15 years has seen its population grow from 4.13 million in 1991 to about 7 million in 2007. This has corresponded with an increase in the size of Bangalore from 226 sq. km. in 1995 to 741 sq. km. in 2007. However, this enormous growth in the population and the size of Bangalore has not been accompanied by a commensurate improvement in the transportation infrastructure and has led to a very severe and persistent congestion.

The general Bangalore congestion problem is decomposable into several significant and somewhat independent pieces. For example, significant new additions to Bangalore such as the offices of the IT industry, the several large Call Centers, and the new International Airport have occurred outside the "core" Bangalore area. But, these additions are not yet well-equipped with the basic amenities for living: hospitals, stores, schools, restaurants, entertainment centers, etc. So, people live in core Bangalore and commute to work in the new developments.

Electronics City Congestion. One significant piece of

the Bangalore congestion problem is the commuter traffic on Hosur Road that links Bangalore to Electronics City. Electronics City is located about 15 km south of Bangalore and hosts IT giants such as Infosys Technologies, Wipro, Hewlett-Packard, Tata Consultancy Services, Siemens, Satyam Computers and Tata Power. An entity, called the Electronics City Industries Association (ELCIA), of which these companies are members, oversees the development of Electronics City. Our work concerns the congestion experienced by the employees of Infosys Technologies on their way to and from work each day. We describe, in gross terms, the problem which our experiment addresses.

There are about 20,000 employees at Infosys Technologies, Bangalore, of which about 14,000 commuters are of interest to us. This latter group of commuters have Bangalore as their base office and are, therefore, able to participate in our pilot. Of the 14,000 commuters, around 9,000 commute by buses chartered by Infosys, 3,000 commute by private automobiles (cars, motorcycles) and 2,000 by other means (typically, public transport). Over 200 buses are used for the morning and evening commutes. Extensive and detailed data is maintained by Infosys on the bus commutes; e.g., commuting times, occupancy of each bus.

The data shows that commuters who leave for work after 7.30 A.M. suffer commute times that are about *1.5–2 times* longer when compared with those who leave before 7.30 A.M. A similar difference in commuting times exists in the evening. This translates to an additional 70–90 minutes of journey time every day! In addition, there is the cost of pollution due to emissions and noise, and the cost of extra fuel. As we shall see in Section 2.1, the huge time and fuel costs haven't deterred commuters; indeed, the opposite is true: the proportion of early commuters has reduced from 29% in 2005 to 16% in 2007. While this is typical commuter behavior in many settings, an additional reason in this setting is the team-oriented nature of work at Infosys: it helps for the entire team to arrive together.

An incentive mechanism. To encourage commuters to travel at less congested times, we initiated an incentive scheme, called INSTANT (for the Infosys–Stanford Traffic project). The scheme awards credits to users every day depending on their arrival time. The credits accrued by a commuter qualifies them for a monetary reward made at the end of each week. Reward amounts varied from Rs. 500 ($10, assuming an exchange rate of Rs. 50/$1) to Rs. 12,000 ($240) and were paid out through a raffle mechanism (details later). The more credit a commuter a commuter had, the higher the reward amount they could win and the higher the chance that they win a reward at all. A total of Rs. 96,000 ($1920) was given out each week to a total of 66 qualified, randomly chosen commuters. About 1900 commuters were rewarded during the course of the program.

The INSTANT project had a significant effect on the commuting patterns of the employees. For example, the number of commuters arriving in various pre-rush-hour periods *doubled*. The average morning commute time per bus commuter, averaged over *all* bus commuters, dropped from 71 minutes to 54 minutes. This translates to about 2600 person-hours per day saved on the morning commute. Detailed results

are presented in Section 2.3.

Remark. The Infosys commuter problem is representative of the commuting experience of employees in the high-tech industry in Bangalore. The congestion in Electronics City is notable as much for its severity as for the fact that Electronics City embodies "modern India." Its congestion problems are mirrored elsewhere, linked by common causes: a rapid increase in opportunity for a large middle class without an accompanying growth in infrastructure. Thus, a successful solution for Electronics City can have a wider implication.

Related literature and other approaches. An early and seminal paper of Vickrey [7] discusses the use of charging as a means of relieving road congestion. Recently, several cities have employed "corridor congestion charging" to combat peak hour congestion; for example, London, Singapore and Stockholm. The idea here is to impose a flat charge on a vehicle entering a congested zone. While congestion charging is effective in reducing congestion, there have been several criticisms; for example it has been criticized that it favors the rich, and that it adversely affects the retail businesses in congested zones. See [16] and the references cited therein for a detailed discussion.

One important aspect of congestion charging, especially relevant to us, is that it cannot be applied to just a subset of commuters. Indeed, aside from the issue of fairness, if a significant subset of commuters were exempt from the charge, then these commuters would be free to congest and would render the scheme ineffective. However, commuters who are made to pay a congestion charge *expect* a reduction in congestion in exchange for their payment because this is the stated aim of the scheme.

By contrast, our approach of paying incentives to decongestors can be applied to a small sub-population. This is due to a fundamental shift in perspective: our approach does not directly aim to reduce overall congestion. Rather, it aims to induce a behavior in commuters that leads to a reduction in congestion; thus, it is more appropriate to view our approach as a *behavior incentive*. By not going directly after congestion, our approach is applicable to a sub-population such as a corporation or a neighborhood. Commuters who modify their behavior unilaterally benefit from reduced commute times and having a more comfortable commuting experience. The money saved by the corporation or neighborhood (in terms of reduced fuel, time and pollution costs) can be used to pay out the incentives. Our experiment can be viewed as an initial test of this hypothesis. We conclude this discussion by further hypothesizing that any scheme that aspires to possess the desirable property of being *incrementally deployable* cannot set congestion reduction as its main goal!

We note another interesting approach to congestion charging which advocate the use of tradeable permits [8] and congestion credits [9]. The main idea here is to issue mobility rights to residents who can use these for themselves or sell the rights to other commuters who have exceeded their quota.

Another interesting thread, which we do not pursue here, is to contrast our problem with the extensive literature on "selfish routing" [14, 10, 6, 13]. Selfish routing studied the ef-

fect of users choosing, from amongst set of alternate routes, that route which minimizes their delay. The delay of the resulting Nash allocation of traffic is compared with the delay under an optimal (centralized) allocation of traffic. The ratio of the Nash and optimal delays has been dubbed in the literature as "the price of anarchy" [14]. In our setting, commuters have a single route and the choice they make is temporal, not spatial. This difference is interesting to explore and we plan do so in subsequent work.

2. THE INSTANT EXPERIMENT
This section describes the INSTANT experiment, conducted at Infosys Technologies, Bangalore, from October 6, 2008 through to April 10, 2009. We describe the problem, the experiment and the results.

2.1 The problem
As mentioned in the introduction, about 20,000 employees commute each day to work at Infosys Technologies using chartered bus, private automobiles or public transportation. Of these, about 14,000 commuters are able to participate in the INSTANT experiment because Bangalore is their base office. Most of these commuters live in Bangalore and travel 15 km on Hosur Road to Electronics City where Infosys is located. Geographically, the situation resembles a funnel, with Bangalore in the conical portion and Hosur Road being the long and narrow pipe (see Figure 1). Most of the congestion occurs at the base of the cone and on Hosur Road.
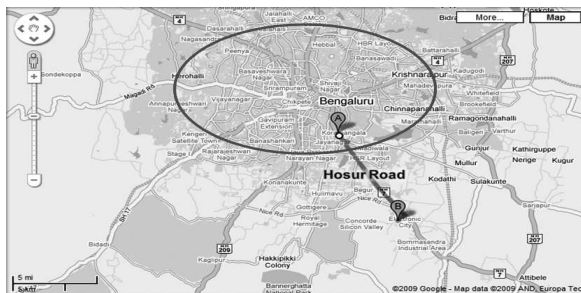

Figure 1: A map of Bangalore showing the 'core' of the city and Hosur Road leading to Electronics City.

Bus data. Of the 14,000 commuters who can participate in INSTANT, about 9,000 travel in one of over 200 buses chartered by Infosys. Infosys maintains very detailed data on the buses, as shown in the table in Figure 2. Each bus is numbered, with the pick up time at the origin and the drop-off time at Infosys marked precisely. The exact occupancy of the bus is also indicated. Similar data is available for the evening commute. In this paper we focus on the morning commute data.

Figure 2: Format of bus data maintained by Infosys.

The bus data provide us a detailed view of the congestion experienced by Infosys commuters each day. Here are the salient points.

1. The data shows that there is a transition around 7.15 A.M. in terms of the departure time of the commuters, the journey times, etc. So, we shall split the data into two (or more) groups, depending on the start time of the journey.
2. Figure 3 shows the monthly average number of commuters according to pickup time. There is clearly a strong preference for later pickup times, and this has become more pronounced with time.
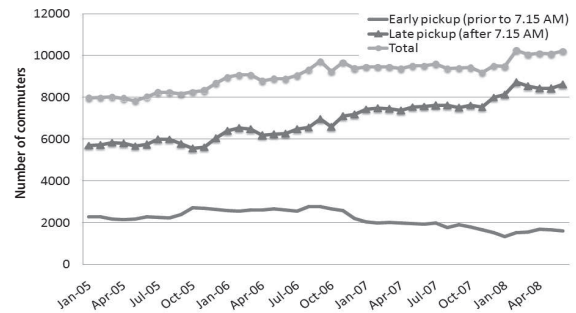

Figure 3: Monthly average number of commuter arrivals.

3. Figure 4 shows the bus occupancy distribution for June 2008. Many of the late buses are seriously over capacity(with standees), whereas the early buses are quite uncongested.
4. Due to commuter preference for late pickup times and their demand for more comfortable rides, more and more buses were deployed to later pickup times. See Figure 5.
5. However, the congestion at the later times is extremely severe! For example, Figure 6 shows the monthly average journey times from Jayanagar, a place from where many Infosys employees commute from. As can be seen from Figure 6, the average commute times are either 30 mins, 45 mins or as high as 75 mins, depending on the pickup time. What's more: the variance in the commute times is quite high at the later pickup times; see Figure 7.
6. Figures 8 shows the average commute times from Adarsh Garden and Minerva Circle, two other areas which house many Infosys employees.
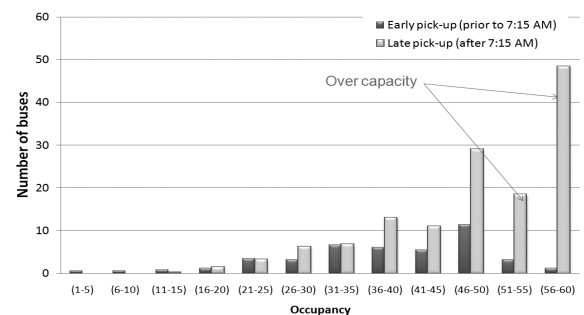

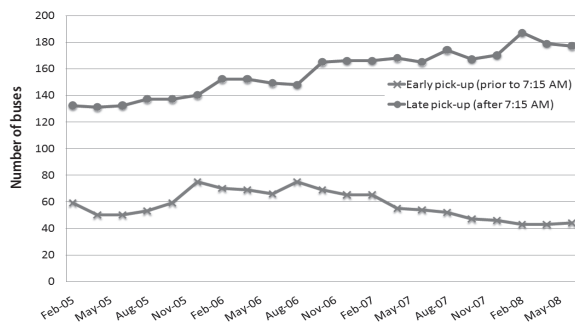**Figure 4: Bus occupancy distribution (June, 2008).**
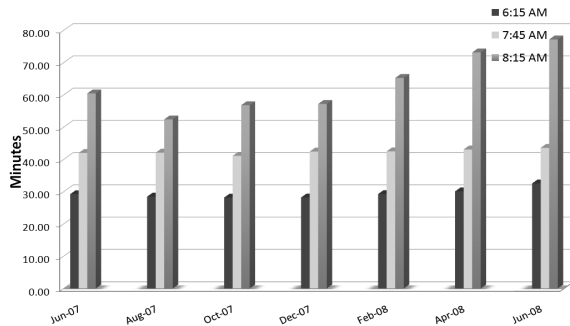
Figure 5: Buses deployed to service the demand.

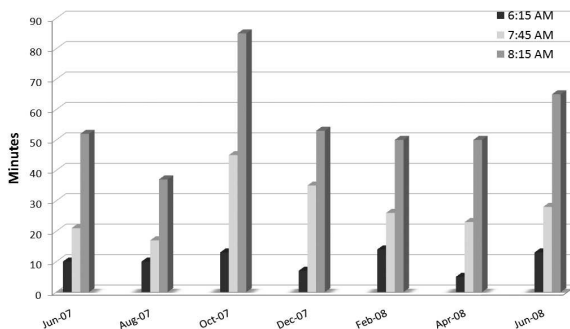**Figure 6: Commute times from Jayanagar to Infosys.**

Figure 7: Difference of the longest and shortest commute times from Jayanagar.
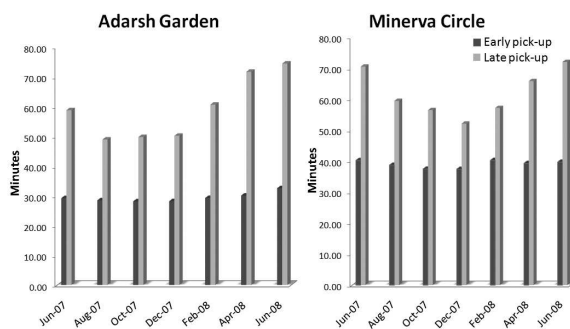

Figure 8: Commute times from Adarsh Garden and Minerva Circle to Infosys.

Fuel cost. As the data has shown, buses in the later pickup times spend about 40 mins extra time on the road in the morning, and there are about 180 buses in this category. A similar statement is true of the evening commute. If these buses were all to travel at less congested times, a considerable amount of fuel would be saved. In conversation with the bus operator, we have established that each bus which commutes the extra time during rush hour consumes at least one more liter of diesel. With diesel priced at about Rs. 40 ($0.80) per liter, the extra fuel cost works out to about Rs. 15,000 ($300) a day.

Private automobiles. As mentioned, about 3,000 employees use cars and motorcycles to commute to Infosys. While we do not have similar detailed data on their commuting times and fuel costs, they are stuck in the same traffic and, hence, suffer the same delays.

2.2 The incentive mechanism

As the data shows, despite having to endure much longer commutes and crowded buses, Infosys commuters preferred later pickup times. In a couple of town hall meetings in July and Sept 2008 the findings of the bus data were shared with the commuters and a proposal was made by the authors of the paper to run an experiment offering incentives to the commuters. This was greeted with a mixture of interest, curiosity and skepticism. This section describes the details of the mechanism and the algorithm.

The incentive scheme was named INSTANT and offered incentives to commuters (both bus and non-bus commuters) for commuting in off-peak hours. The scheme was launched on Oct 6, 2008, by Mr. N.R. Narayanamurthy (co-Founder and Chief Mentor of Infosys) and lasted until Apr 10, 2009.

Overview: The scheme awards credits each day to employees based on their arrival times. Each week the cumulative number of credits of each commuter is used by an algorithm to choose commuters who will win monetary rewards. The main feature of the algorithm is that the more credits a commuter had earned the higher the amount of prize money they could win and the higher the chance that they could win a prize. The algorithm has three components: credit allocation, weekly reward draws and credit deduction.

Reward pyramid: The scheme has a pyramidal reward structure with four levels, as shown in Figure 9. The reward amounts are Rs. 500, Rs. 2,000, Rs. 6,000 and Rs. 12,000 in levels 1, 2, 3 and 4, respectively. The total sum of money in the pyramid is Rs. 96,000, distributed equally among the four levels. (Note that this amount is roughly equal to the total cost of extra fuel per week which was estimated at Rs. 15,000 per day.) Thus, there are 48 prizes worth Rs. 500 each, 12 worth Rs. 2,000, 4 worth Rs. 6,000 and 2 worth Rs. 12,000. Each level has a minimum number of credits needed for qualifying at that level. This number is 3, 7, 12 and 20 for levels 1, 2, 3 and 4, respectively. A commuter who qualifies at one level automatically qualifies at all lower levels.

Credit allocation: Every working day a commuter will be awarded credits according to his/her swipe-in time. A swipe-in before 8 A.M. will fetch 1.5 credits and a swipe-in
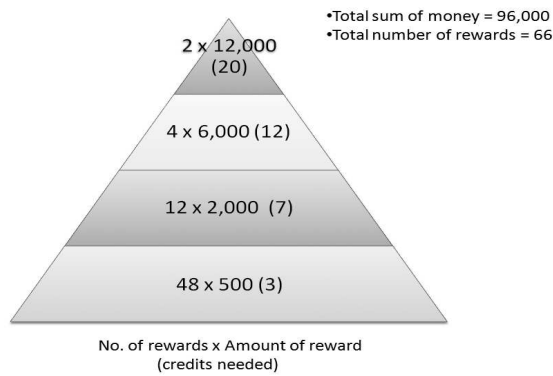
Figure 9: The reward pyramid.

Figure 10: Flow chart of the incentive mechanism.

between 8 A.M. and 8:30 A.M. will fetch 1 credit. No credits are awarded if swipe-in is after 8:30 A.M. Commuters accrue credits in their accounts.

Weekly reward draws: At the end of each week, the algorithm determines the level at which a commuter has qualified. Note that commuters who have fewer than 3 credits are not qualified for the draw. To select the winners, the algorithm starts from the top-most level (Level 4) and randomly draws the required number of winners (2 at Level 4). Commuters who do not win at this level, move to the next lower level and take part in the draw at the lower level. This process is repeated for all the levels. If there are fewer commuters qualified at a level than the number of rewards at that level, then the surplus money is allocated to lower levels.

Credit deduction: After each draw, credits are deducted from both the winners and non-winners. This ensures that commuters arrive early frequently enough if they want to have credit balances, and also ensures that a winner will have to build up their credit balance over a few weeks before being able to win again (this gives others a chance to win). The number of points deducted from a winner equals the number of credits needed to qualify for the level they had reached before the draw (e.g., 12 points will be deducted from a winner who had qualified at Level 3 before the draw). Note that the number of credits deducted from a winner does not depend on the level at which they won the prize, which can be lower than the level at which they were qualified. The number of credits deducted from non-winners equals the difference in the number of credits required for qualifying at their level before the draw and the level immediately below it (e.g., 5 points will be deducted from a non-winner who qualified at Level 3). It is not hard to see that the values of the credits and deductions are such that the maximum credit balance a commuter can accrue is at most 22.

Figure 8 shows the flow chart of the incentive scheme, depicting the implementation process.

2.3 Results

There are several quantities which we have monitored during the course of the experiment—the 27 weeks in the period Oct 6, 2008 to Apr 10, 2009. The most important are: morning
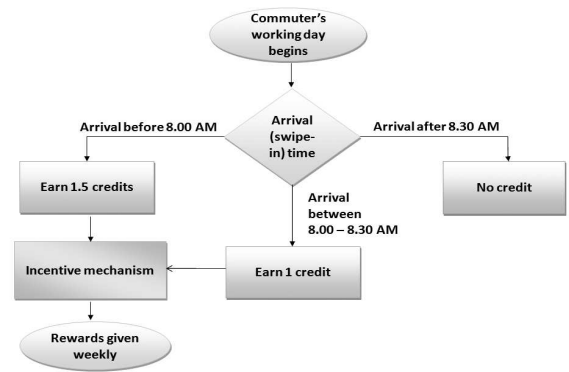
arrival times, morning commute (journey) times, bus occupancies and the credit balances of the winners before the draws. We present a sample of the results below.

Figure 11 presents the weekly average number of commuters arriving before 8 A.M., 8.30 A.M. and 9 A.M. during the course of the experiment. Some numbers from before the start of the experiment are also shown for reference.
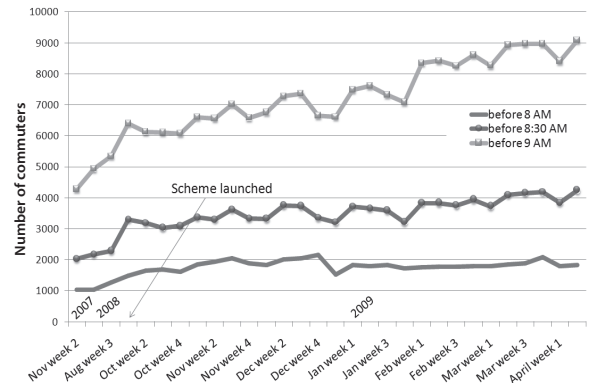

Figure 11: **Average number of commuter arrivals over the period of the experiment.**

The data shows that the number of commuters arriving before 8 A.M. has increased to about 2,000 from about 1,000; the number of commuters arriving before 8:30 A.M. has gone up to about 4,000 from about 2,000; the number of commuters arriving before 9 A.M. is around 9,000, up from about 5,000. Thus, the number of commuters arriving in each segment has roughly doubled over the period of the experiment.

Figure 12 shows the bus occupancy distribution in the month of April, 2009. Contrasting this with Figure 4, the occupancy distribution in June, 2008, we see that the number of buses that are over capacity has significantly reduced while the number of buses with a good occupancy (30–50) has increased.

Remark. Due to commuter demand, and owing to their interest in the earlier arrival of their buses, the pickup times of about 60 buses was *advanced* by about 15 minutes (some

by as much as 30 minutes). Several buses were shifted from arrival after 9.30 A.M to before 8.30 A.M.
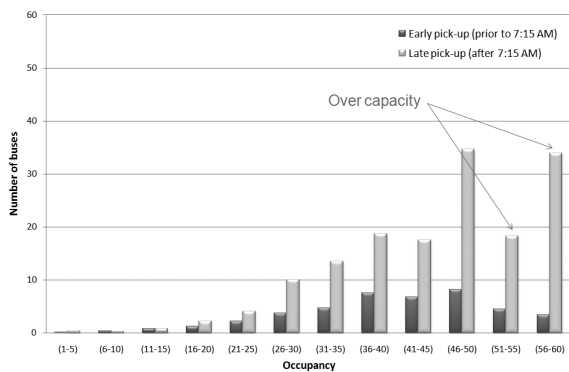

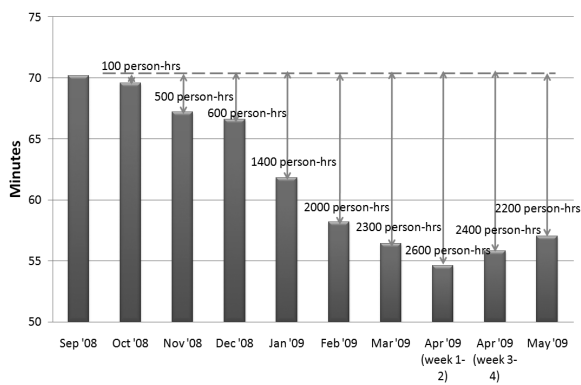**Figure 12: Bus occupancy distribution (April 2009).**

Figure 13: Average morning commute times and total savings in person-hours.

Figure 13 shows the average morning commute times of the bus commuters over the period of the experiment. The average morning commute time per commuter (averaged over all 9,000 bus commuters) came down to 54 minutes from around 71 minutes before the scheme was launched. This has resulted in a net savings of about 2600 person-hours per day.

Interestingly, while we observe a steady decrease in the average commute time during the experiment, the average commute time has *increased* since the end of the experiment. We are continuing to monitor the numbers.

3. CONCLUSION AND FUTURE WORK

We have described the INSTANT project, an incentive mechanism to encourage commuters at Infosys, Bangalore, to commute at less congested times. The project has been a success: it succeeded in attracting a large number of commuters to travel at off-peak hours, led to a *advancement* of pickup times in the bus schedule, been greeted with enthusiasm by commuters, management and the Indian national newspapers [4, 3, 2]. There is an interest in deploying it more widely in Bangalore and elsewhere.

Three features of our approach stand out and require fur-

ther study: the idea of paying incentives to decongestors, the paying of large random rewards, and the possibility of incremental deployment. We are actively engaged in understanding these features through a combination of theory and (quite likely) through other deployments.

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