NextDrop

www.nextdrop.org

Thejo Kote

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Introduction

"Will I get water today?" In almost all of the cities in South Asia and at least a third of those in the rest of Asia, Africa, and Latin America, families face this question every day.[1] These millions of households have a piped water supply; however, water is only available through these pipes for a few hours at a time. In Hubli-Dharwad, a city of 1.1 million people in the state of Karnataka, India, where we are conducting a pilot, the utility pipes in water on a four day rotation. Depending on the season and the neighborhood, water can take up to <u>eight days</u> to arrive. In most households, someone must be present in the house when the water is on. Many low-income households share taps, waiting turns to collect water, while low pressure in some areas requires descending into a pit to retrieve water a bucket at a time. Large storage containers – and the space to put them in a crowded urban settlement – can be prohibitively expensive, so a multitude of storage containers are used to collect enough water to last for five days and water-intensive chores, such as clothes and dish washing, are often saved for that day. Households lose hours each day waiting for water, are stressed by water scarcity, and regularly need to substitute with unsafe sources of water. Households lose an estimated <u>7 days each year</u> waiting for the water, which equates to a city-wide loss of over <u>1.2 million days per year</u>. Hubli-Dharwad is only one of over 400 cities in India, each with populations over 100,000, which face similar unreliable piped water supply.

NextDrop leverages the recent proliferation of mobile phones in India to provide households with <u>*accurate*</u> and <u>*timely*</u> information about local piped water delivery, while also enabling water utilities to access real-time information about the status of their distribution system. In Phase 1 of our pilot project, NextDrop sourced this information from water consumers: by providing micro-payment incentives, consumers notified our SMS based system when the water began flowing, and NextDrop in turn notified residents in the same locality of the current delivery of water. In Phase 2, we have partnered with the public water utility - the Hubli-Dharwad Water Board - and will now receive updates directly from utility employees who physically open the valves in order to provide advance notice of water delivery.

NextDrop is a multi-disciplinary team of students from the UC Berkeley School of Information, School of Public Policy and Civil and Environmental Engineering department. We started working on the project in late 2009. In this report, we will present the motivation for our work, progress so far and share what we have learned creating a mobile phone based information delivery system.

[1] World Health Organization. (2000). "Global Water Supply and Sanitation Assessment 2000 Report." World Health Organization and the United Nations Children's Fund, Geneva.

* Cover page photo by Mikhail Esteves

Our goal with NextDrop is to generate high quality water timing information using inputs from utility employees in the field and local residents to alleviate the social costs of intermittent water. In addition, by generating an independent record of true water delivery outcomes, we believe we can help communities organize against inequitable distribution and reduce corruption. Ultimately, our vision is to create a sustainable and scalable social enterprise that can improve outcomes for hundreds of millions of people affected by intermittent water throughout India and all of South Asia.

Motivation

Unreliable delivery of piped water is a serious problem throughout cities in Asia, Africa, and Latin America. While there is a growing emphasis on the reform and repair of infrastructure, most proposed solutions are long term, capital-intensive renovations that are prohibitively expensive for many resource-constrained cities. For example, in Hubli-Dharwad, a recent World Bank pilot providing continuous water cost $39.5 million to reach only 10% of the city's population.[2] The field is ripe for an *information-based* solution that can reduce unreliability in the near term.

Current Household Adaptations to Unreliability

- Forgoing work, school (for children), social, or community activities to wait for water delivery
- Buying expensive water from private suppliers or substituting to unsafe ground or surface water
- Walking long distances to places where water is available

Initial feasibility study – Impact on Hubli-Dharwad, India

In Hubli-Dharwad, where we have conducted an initial feasibility study, we conservatively estimate the losses resulting from discrepancy between printed schedule and actual water delivery to be:

- Opportunity cost from waiting for water
  - Household loss: **7 work days / year**
  - City – wide losses: **1,265,600 work days / year**
    - Monetized opportunity cost: **$1,569,244 / year**
- Health costs from substituting to unsafe water sources when water is not delivered on schedule, leading to increased diarrhea incidence
  - Household wages lost from work days missed due to illness: **$5.58 / year**
    - City – wide wage losses: **$1,010,367.68 / year**

[2] World Bank (2004). Project Appraisal Document on a Proposed Loan in the Amount of US$39.5 Million to the Republic of India for the Karnataka Urban Water Sector Improvement Project E. I. S. Unit and S. A. R. Office, The World Bank.

  - Household health costs (hospitalization & doctor's visits): **$10.17 / year**
    - City – wide health sector costs: **$1,838,891.60 / year**

A Global Issue

There is a huge base of households worldwide that could benefit from reliable information about the delivery of water:

- No major city in India has continuous water supply, and 27.3% of the 1.15 billion population lives in urban areas, which equates to an urban population of 315 million people[3]
- At least 1/3 of the urban Africa and Latin America and 1/2 of Asia is estimated to have intermittent water supply[4]
- Normal provision of water in India is 4-5 hours per day[5] though there is much heterogeneity between cities and seasons

To gauge scalability outside India, NextDrop conducted a baseline survey in Dschang, Cameroon to evaluate market potential in other diverse geographic regions. After surveying 115 families, the results indicate that NextDrop has scalability potential in this area. 74% of respondents reported the absence of a water schedule. 55% of respondents reported learning that the water has come by leaving the tap on and listening for the sound of water, while 25% said they gather this information from their neighbors – both similar to strategies used in Hubli-Dharwad. 31% of respondents reported waiting more than 6 hours for water, and 31% reported getting water for two hours or less- thus making a service like NextDrop highly valuable. Finally, 44% of all respondents reported having a mobile phone while collecting water.

Using Information Technology to Close the Market Gap – Mobile Technology Statistics

In recent years, like much of the developing world, India has seen a dramatic increase in the adoption of mobile telephone services. The increase in mobile access and the low cost of usage has created an immense opportunity for information provision through mobile technology.

- Tele-density (Telephones per 100 people) in India as of June 2010 was 56.83% , with 94.61% of this being wireless[6]
- In urban areas like Hubli-Dharwad, the wireless tele-density is 128.2 %[7]
- The number of mobile phone connections in India is expected to grow to more than one billion by 2015[8]

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[3] "Census Data Online: Population." (2007). I. Census of India: Office of the Registrar General & Census Commissioner, ed., Government of India.
[4] WHO/UNICEF 2000
[5] Zerah, M. H. (1998). "How to assess the quality dimension of urban infrastructure: The case of water supply in Delhi." Cities, 15(4), 285-290.
[6] TRAI (Oct. 2010) The Indian Telecom Services Performance Indicators
[7] TRAI (Oct. 2010) The Indian Telecom Services Performance Indicators
[8] Economic Times (2009) http://economictimes.indiatimes.com/News/Economy/Finance/India-to-have-billion-plus-mobile-users-by-2015-executive/articleshow/5242284.cms

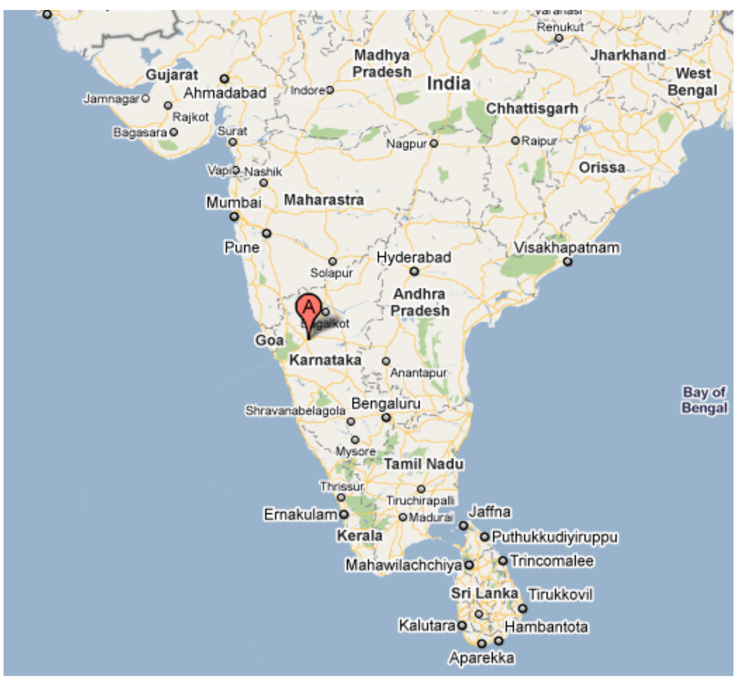
- Voice and SMS rates are some of the lowest in the world[9]

Addressable Demographic

In cities like Hubli-Dharwad, almost all residents with intermittent supply could benefit from information about water availability. While lower income residents bear the greatest cost of unreliable water in the form of time loss, even upper-middle income households, who have sophisticated coping mechanisms such as underground storage tanks, need to know when piped water is available. Through our ethnographic research, we found that majority of households collect drinking water by hand, separating this water from their household use water in small containers when municipal water is available.

Pilot in India

To pilot NextDrop, we selected the city of Hubli-Dharwad in the state of Karnataka. We chose this city because of team member experience researching intermittent water in the area and because government, at both state and local levels in Karnataka, is among the most progressive in India in terms of their willingness to try out information and communication technologies for public good. Many well-known policy innovations, such as the Bhoomi land records project, were first implemented in Karnataka.



In the summer of 2010, two team members travelled to Hubli-Dharwad to set up the NextDrop pilot. We were supported by grants from the Gates Foundation via the UC Berkeley School of Information, the Center for Information Technology Research in the Interest of Society, and Clinton Global Initiatives. In addition, we arranged to receive local support from the Deshpande Foundation, a well regarded NGO with a Center for Social Entrepreneurship at BVB Engineering College in Hubli.

Baseline Study

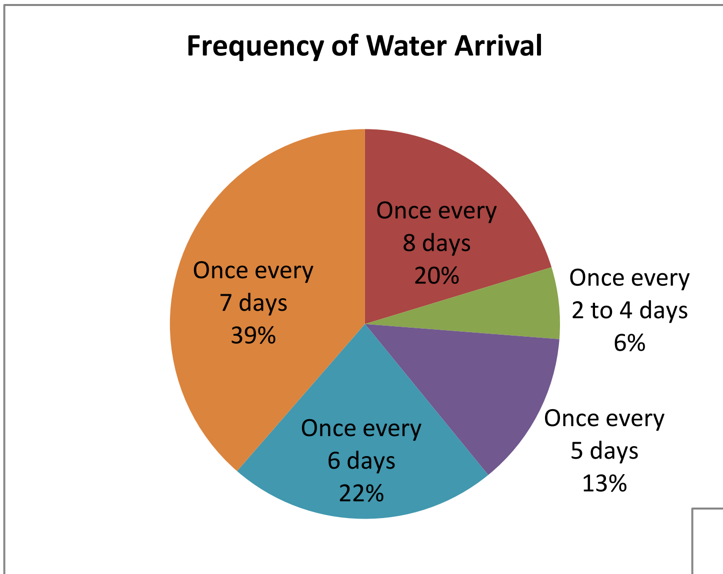
Once in Hubli, team members conducted ethnographic research, with the goal of understanding coping behaviors, demand for water timing information, and the feasibility of using an information-based solution. We hired enumerators through the Deshpande Fellowship Program in Hubli to survey households in the areas nearby the Deshpande Center for Social Entrepreneurship. In total, 205 surveys were completed in the neighborhoods of Sainagar and Vidhayanagar,

[9] TMCNet, http://www.tmcnet.com, 2010.

focusing only on households with in-home taps. The predominately middle-income and lower-middle income households surveyed fell in the middle of the spectrum in terms of the severity of their water scarcity and unreliability problems compared to other areas of the city.

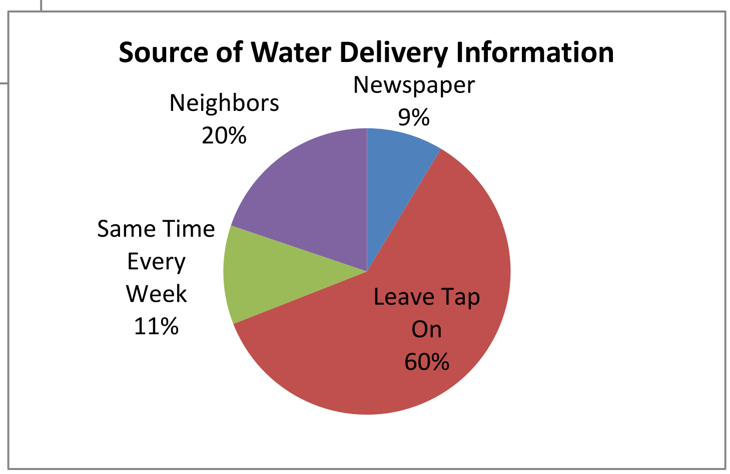
Baseline Results

On average, households in the neighborhoods reported receiving water once every 6 to 7 days during this part of the year.



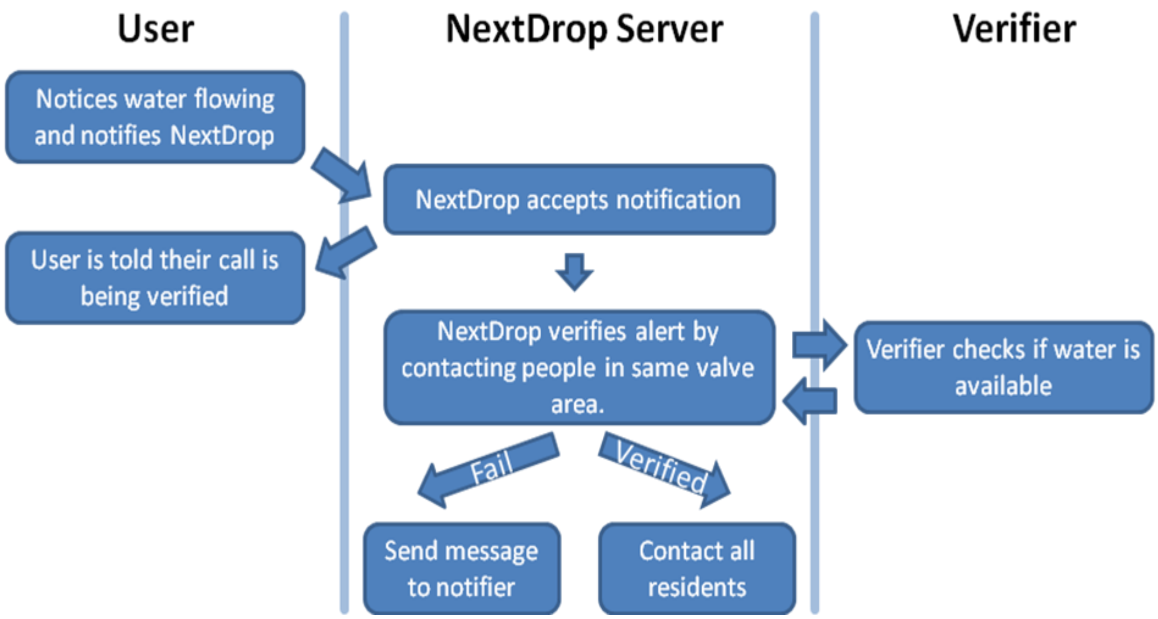
72% of households reported receiving water at a different hour of the day each time it arrives. Households received the water for 6 hours on average, with women using this entire period to do household tasks including washing laundry and dishes, in addition to collecting drinking and domestic water for storage.

When we asked people how they know when the water will come less than 10% reported obtaining the information from the newspaper. The majority of households (60%) reported leaving the tap open and waiting to hear the sound of running water. 20% of households reported finding out from their neighbors when water will arrive. Finally, 70% of respondents reported having access to a cell phone at the time they collect water.

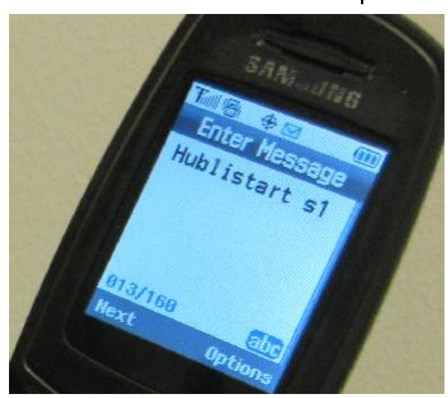


Crowdsourcing System Prototype

Concurrent with our field research, we built an SMS-based system with the capacity to crowd-source information on water availability and deliver updates via SMS in an automated fashion. The figure below depicts the information flow through the system.



The NextDrop system worked in three stages: notify, verify, announce. Each stage could be accomplished through an SMS interface. During the notify stage, residents notified the system that water is flowing at their home. To verify the notification, other users in the same valve area were contacted and asked if water was flowing in their home. At this stage, NextDrop tried to generate two positive confirmations by randomly choosing residents in the valve area. If NextDrop was able to successfully complete the verification, it progressed to the announce stage where all the users in the valve area were contacted with the news.



We encouraged residents to use the system through monetary incentives for notifications and verifications. These incentives helped offset the cost of outgoing calls/SMSs (incoming calls/SMSs are free). Because many mobile phones do not have font support for the local language, Kannada, the SMS version uses English prompts and responses.

Phase 1 of the Pilot

In July 2010, we launched the first iteration of our pilot, after recruiting approximately 180 families in 5 valve areas to provide us information and receive updates from us for free. When recruiting families into the pilot, we set the expectation that the pilot was a temporary project. In general, we often conducted brief surveys (with the same questions asked as in our baseline study) as a way to engage potential pilot participants. We also used our association with Deshpande Foundation, which enjoys a strong reputation locally and helped us gain credibility with potential users.

Through the recruitment process and studying usage on a day to day basis, we found that many of the families interested in participating found it difficult to use the SMS system we had initially designed. In particular, the requirement of sending us a specific line of text in English—such as "Hubliwater v1" to report water arrival or "Hubliwater yes" to verify a notification report—seemed to trip up many participants who made errors. In light of these issues, we decided to switch to a Wizard of Oz system, in which our local employee would accept notifications through calls, missed calls, and text messages, and do verifications via phone calls. Finally, he would use the SMS-system we built to push notifications to all participants within the geographic area receiving water at the same time. This process encouraged us to create an Interactive Voice Response (IVR) system and conduct a comparative study of the two systems to better understand the two user interfaces in the context of our use case. The study and results are described in detail in the Appendix.

To motivate users to send us timely notifications and verifications and defray the SMS and voice costs, we offered to provide 5 Rupees of phone credit (approximately US 10 cents) to the first individual to notify us water had arrived and to two verifiers. In defining the pilot neighborhoods, we also met with local water utility employees who helped divide neighborhoods geographically by valve areas. We further offered these local employees the opportunity to participate in our system and received permission from the Hubli-Dharwad Water Board and Hubli-Dharwad Municipal Corporation to solicit their participation.

Phase 1 Results

Since July 2010, we have collected over 250 data points and distributed over 50 water availability updates to 30-40 households at a time using SMS. Our focus throughout this phase of the pilot has been to test our ability to successfully crowd-source water timing information, reach users in a timely manner, and gain a nuanced understanding of information flow at the water utility.

In terms of crowd-sourcing, our most encouraging and robust result is our 100% success rate crowd-sourcing verification information. Over the course of our pilot, we have never received a water availability notification which we were not able to verify with inputs from two other users. In addition, almost all verification has been completed within 15 minutes of the initial notification (or water-delivery time, in the case of advance notification).

In the tables 1 and 2 below, we provide two weeks' worth of data which illustrate both the variability of water delivery and issues with data collection and participation in our pilot. The table shows sequential water delivery across the 5 pilot areas. SMS push refers to the time at which we sent out an update to all users in the areas.

Table 1: Snapshot of NextDrop Pilot (October 17-October 23)

Area	Scheduled Delivery Period	Date	1st Notification	Verification 1	Verification 2	SMS Push
Lingrajnagar 1		10/20/10	*2:51pm	2:55pm	2:59pm	3:06pm
Lingrajnagar 2		10/20/10	4:50pm	4:53pm	4:55pm	4:58pm
Sainagar 3	7:30pm-3:30am	10/22/10	*8:15pm	8:24pm	8:25pm	8:26pm
Sainagar 1	3am-10am	10/23/10	*4:30am	4:33am	4:40am	4:45am
Sainagar 2	8am-2pm	10/23/10	8am	8:09am	8:12am	8:14am

*1st Notification provided by utility employee.

Table 2: Snapshot of NextDrop Pilot (October 24-October 30)

	Scheduled Delivery Period	Date	1st Notification	Verification 1	Verification 2	SMS Push
Lingrajnagar 1		10/26/10	**11:30am	11:57am	12:00pm	12:03pm
Lingrajnagar 2		10/26/10	**3:00pm	3:20pm	3:21pm	3:22pm
Sainagar 3	7:30pm-3:30am	10/29/10	**11:50am	12:37pm	12:40pm	12:46pm

** Utility employee provided advanced notification (i.e. water will be available in 15-30 minutes)

Lessons from the 1st Phase

As illustrated by the data points above, we were unable to source water availability information in 2 valve areas in Sainagar during the last week of October. Notably, the areas where we did not receive a notification receive water at particularly inconvenient times—particularly Sainagar 1, which receives water extremely early in the morning.

The tables also illustrate that utility employees have often been a source of information for us, as they have the ability to notify us in advance of residents and they are not occupied with the process of water collection. Finally, we see that even when water arrives at an inconvenient time (4:30am), it is still possible to crowd-source verification information quite rapidly. While this is only a snapshot of our data, it is reasonably representative of the broader patterns.

As a result of our experience, we implemented several changes to our model:
Early into our pilot (August 2010), we ceased to pay individuals for verifications, as they incur no cost in receiving and responding to our verification requests when we initiate the call. We saw no significant difference in participation after this change. At the same time, we also increased payment for the 1st notification to 10 Rupees.

Based on the difficulty of crowd-sourcing water delivery information in areas like Sainagar 1 & 2, we felt we needed to examine alternative strategies for getting consistent participation. Strategically, we decided to focus on working more closely with the water utility, with the objective of getting more support from them and getting participation from employees in the field.

Success Factors and Challenges during Phase 1

Recruitment and Retention

To raise awareness and help participants keep NextDrop in mind, we distributed stickers displaying our contact number to be placed by the tap. We also frequently followed up with households early in the pilot to see if they received our updates and to confirm that we had registered households in the proper valve area.

Challenges

One of the biggest challenges we faced through our recruitment process was getting the phone number for the individual who engaged in water collection—particularly if the person collecting water was a woman. For cultural reasons, it is normal to give out the telephone number of the man of the household. While in a few instances, pilot participants explicitly asked us to provide our updates to their spouses, generally, we have not tracked who in the household receives our updates.
In addition, early in the recruitment process, we faced a challenge of explaining our service, and in particular, articulating both the information we provide and our micro-employment model (cell phone credits we offered for updates). One concern was that our micro-employment model became too central in our pitch to potential users, and that users came to associate the service with this aspect of the service.

Data Collection

Throughout our pilot, we have been much more successful at getting verifications than getting 1st notifications. In addition, a large percentage of our notifications come from utility employees.

Data Distribution

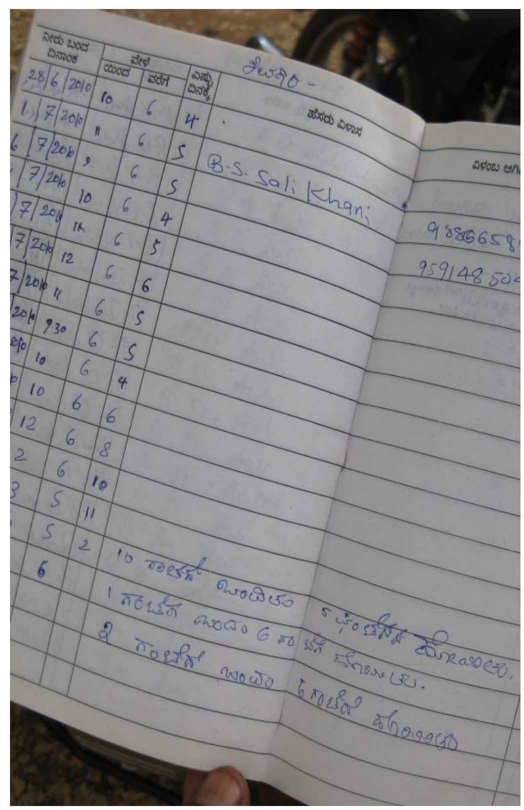
Through our interviews both during our baseline analysis and during the course of our pilot, we learned that families would strongly prefer to receive advanced notification prior to water arrival than a real-time update. While we had hypothesized that over time we might be able to make predictions using patterns in the data and the rotational schedule, we did not receive consistent information in enough sequential areas to make this possible. However, through our study of the water utility, we identified an alternative approach to advanced notifications which we have implemented in phase 2 of the pilot.

Phase 2 of the Pilot

The first phase of the pilot was a very good opportunity for us to learn about the process of intermittent water delivery, the usability challenges in providing information updates through mobile phones and the structural inefficiencies which led to the situation where residents of urban areas did not have reliable information about when the water would actually arrive. While there are many facets which lead to the underlying uncertainty in intermittent supply networks like low quality distribution networks, poorly designed hydraulics, operational inefficiencies etc., in this report, we only focus on the flow of information in the system.

Information Flow in the Water Delivery Network

As we studied the current system of information flow, the reasons for the water utility's inability to provide reliable information about water availability became clear. In the current system, engineers in the utility draw up a schedule which specifies how water should be distributed across different sub-areas of the city in a rotational basis. Though the actual schedule has a time associated with every delivery, in reality, water is never delivered at that time. The main reasons for this are:



- Pumps cannot operate due to power failures.
- Pipe breakages and other damage to the network elements.
- Valve men at the last level who are responsible for the implementation of the schedule are unreliable and do not release water at the right time, or are corrupt and accept bribes to release water to a different area.
- Pressure at the local level by influential politicians or other locals force the water utility employees to break the schedule.

When the schedule is not followed for these reasons, the utility has no way of tracking it. Once the schedule is created and communicated to the engineers and valvemen who are responsible for implementation, no information flows back into the system about what actually happened. The picture on the right shows logbooks used to track events occurring in the system. The utility employees capture a lot of information in this way – when they open and close valves, switch pumps on and off, hourly level of water in the reservoirs etc. But, the information never goes anywhere and is not actionable. They remain in the books till there is a complaint by a resident, for example, and verification is required. We realized that if only we could capture the information that utility employees were collecting anyway in a more efficient way, we could then provide accurate and reliable information to residents.

In the western world, this problem does not exist because the information is collected using sophisticated sensors and aggregated into a centralized location from which it is acted upon. But, this is not an option in the developing world. The challenge is to create a very low cost system which can collect the information and send it to a centralized place in real time.

Low Cost Smart Grid

Based on what we learned, we created a low cost smart-grid "lite" system using mobile phones to collect and aggregate information in real time across the network into a central location, making it accessible and readable by both senior engineers of the water board and residents of the city. As part of this system, utility employees in the field are the sensors and they will be required to notify our system by making a phone call when they open and close valves and "feeder" valves across the city. This does not require a major change in behavior as they are already capturing the information in their log books. Capturing the information in real time will allow the dissemination of accurate and reliable information 30-60 minutes before water starts flowing in a valve area and in real time once the water starts flowing.

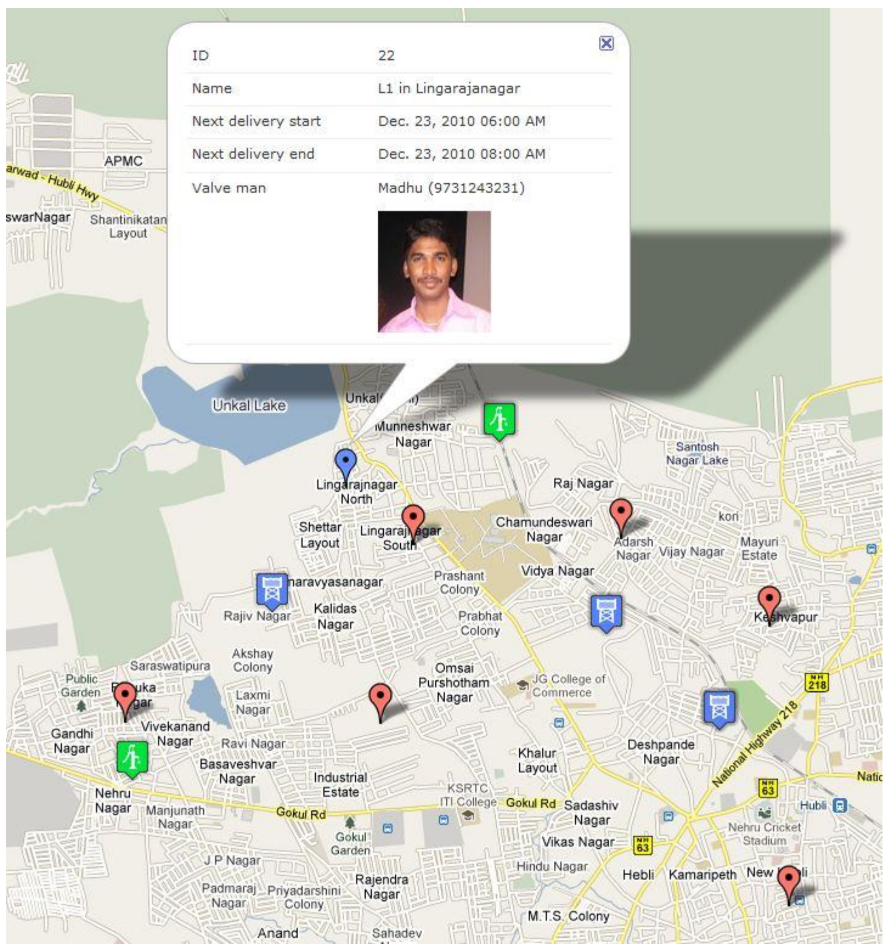
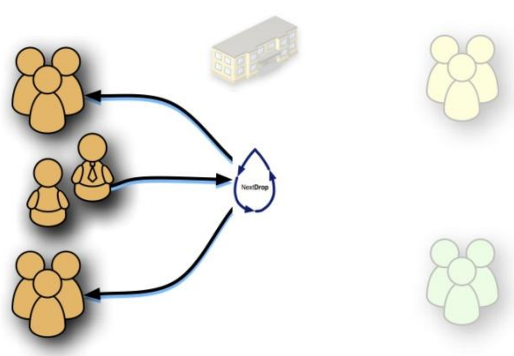


Figure 1 Screenshot of the dashboard from the low cost information collection system being tested in Hubli, India.

We built and demonstrated a prototype of such a system to senior engineers in the water utility in January 2011, and it was received with enthusiasm. We have now started a pilot of this system with their active participation. We have obtained the support of the Commissioner of Hubli-Dharwad to begin the next phase of the pilot, and identified 4 geographic areas for testing. We have trained the relevant employees of the water board and have deployed the system in the field.

Figure 7 shows a screenshot of the dashboard, taken from our functional prototype. Using this system, engineers at the utility can track the status of a variety of elements in the water system in real-time, including pumps, reservoir levels, and the opening of "feeder" valve and neighborhood valves. We are currently working with engineers at the utility to tailor this system to the needs of the utility.

Verify information using crowd-sourcing



The last piece of the solution is to use the power of the crowd to verify the information provided by Water Board employees. For example, when a valveman updates the system that he has opened a valve, the system will contact 2-3 people in the same valve area at random after 15 minutes and ask if water is flowing in their home. This way, the system can verify if the valve was actually opened. If the system is unable to verify that it was opened, it could be that there is a genuine issue in the network, or that the valveman never opened it. This is a very effective way to introduce a feedback loop into the system and curb corruption and inefficiencies.

Over the next year, we anticipate refining our system in collaboration with the water utility and extending our service throughout Hubli-Dharwad. Our immediate target is to provide information to 1000 households across 25 geographic areas in Hubli-Dharwad by March 2012.

Future Opportunities

NextDrop has the potential to reduce inefficiencies around unreliable, intermittent water supply by providing local and timely information about the delivery schedules. This same model of information collection and dissemination could be adapted to other scenarios besides water, such as provision of information about availability and timings of irrigation water, electricity, shipments of aid and health care goods, agricultural extension visits, pensions or salaries availability (from government schemes), etc. The base system NextDrop has developed is useful in any sector with long waits for any type of public service, especially in systems where some fraction of users can be incentivized to share information that is useful to many. Additionally, the data we collected can build previously unavailable transparency and accountability into public service delivery systems by revealing inefficiencies or corruption. We plan to build a trusted channel and system for delivery information on piped water availability first before expanding to other opportunities.

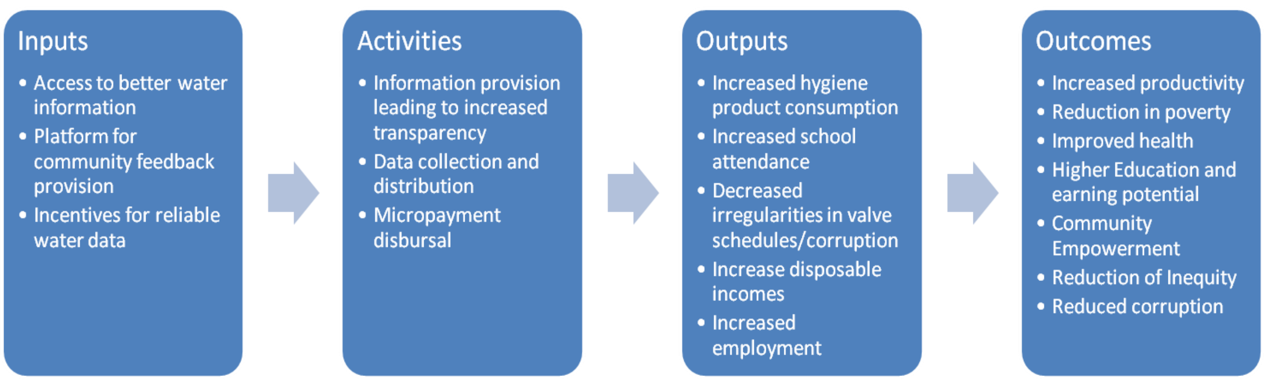
Social Impact Analysis

In this section, we analyze the social impact of intermittent water supply.

Theory of Change

In communities with intermittent water, access to reliable, timely information about water delivery will help households save time, reduce stress, and improve health. Crowd-sourced public data about water delivery will bring transparency and accountability into the system and help water boards reduce corruption and increase efficiency.

Social Impact Value Chain



Social Impact Indicators

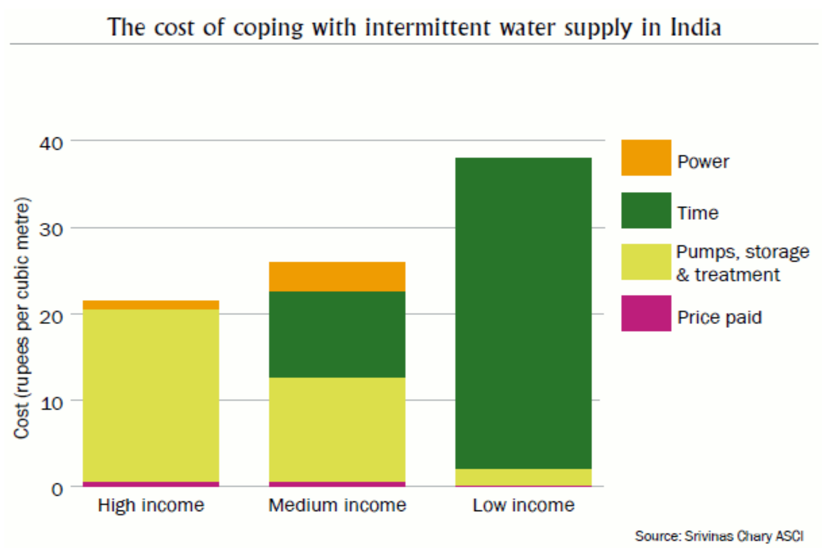
To evaluate the efficacy of NextDrop, we have identified several key impact indicators that we expect NextDrop to have an influence on. The social benefit cash flow model has been based on these indicators, and these will continue to be measured using surveys and publicly available data.

Recent research suggests that a large fraction of households' total costs from intermittent water manifest in the form of times losses.[10] It is in this area, specifically in the amount of time households lose waiting for the water to arrive, that we expect NextDrop to generate some of its most profound impact. We will use surveys during the pilot phase to quantify the benefits provided by NextDrop services by evaluating household-level factors before and after NextDrop service. This includes measuring time spent waiting for water and frequency at which households switch to alternative services (e.g.

[10] Chary, Srinivas "The cost of coping with intermittent water supply in India." Global Water Intelligence. Vol 10, Issue 5. May 2009

borewells or tanker trucks). This is used to quantify the opportunity costs avoided by NextDrop and also understand whether households are able to conserve water and plan more effectively by using the service. Additionally, we expect that there would be health gains as substituting to typically unsafe urban groundwater, even only a few times per year, can lead to costly consequences of illnesses, including medical expenditures, lost days of school and work, and costs to the health sector. Additionally, illnesses and time spent waiting for water can affect children, who may need to miss school. Elements not yet included in the social cash flow benefit model that we will measure on an annual basis include increases in disposable incomes and hygiene product consumption, all of which can multiply our overall social impact.

In addition, NextDrop's information has the potential to spur communities to organize against corruption by providing citizens, utilities, and government officials with access to actual delivery patterns and highlighting discrepancies and possible areas of corruption. NextDrop will be collecting extensive data on the timings and frequency of water delivered in various geographic areas of the city; this information, which can be made publicly available through internet-based mapping, can be made more broadly accessible by journalists and students who may wish to use the information to lobby for more equity in water distribution. To measure this impact, we will use methodology developed by Transparency International to calculate the Corruption Perception Index (CPI) for our target communities, which will indicate our influence in reducing corruption and equalizing distribution in the water system.



Social Cash Flow Benefit Calculations

Using 2006 census data from Hubli-Dharwad, we approximate the costs to households and society as a result of water delivery that does not corresponding to the set schedule. The quantitative analysis focuses on four key areas: 1) opportunity costs to households due to time loss; 2) days of school lost due to time loss in the child population (not monetized); 3) health costs based on coping behaviors, and 4) health sector savings. These calculations, detailed in the Appendix, are based off of 2006 census data from the city of Hubli-Dharwad, and relies on standard methodologies for estimating illness due to waterborne diseases (through a Quantitative Microbial Risk Assessment) and estimating the costs related to these illnesses and its affect on school-age children (World Health Organization cost-effectiveness analyses methodology).

Key Metrics

Based on our projections, we estimate the NPV of Social Benefits generated at $15.9 million over the 5 year period, which does not include the benefit of approximately 550,600 missed school days averted. We further estimate a social benefit-to-cost ratio of 7.4:1.

Opportunity Cost from Time Spent Waiting

Water delay by one day beyond the printed schedule of 4 days corresponds to an opportunity cost of one day of lost income at daily poverty line wage (i.e., if water comes every 5 days instead of 4, it is assumed that household lost a day of time in waiting). Based on 2006 census data, this translates to 7 days of work lost per household per year (detailed calculations are included in the Appendix), with a financial loss per household, with time valued at the minimum wage, of $8.93 per year.

Direct Patient Cost

Data on expected health impact (cases of waterborne illnesses per person per year) were based off of a quantitative microbial risk assessment for the major waterborne illnesses affecting urban populations when forced to switch to unsafe sources infrequently.[11] Based on this information, the estimated cases of diarrheal illnesses averted per year (cumulatively) is 0.2729 for adults and 0.0834 for children. Data for averted health-related costs was calculated using the World Health Organization cost-effectiveness procedures and data.[12] The yearly direct patient costs averted (adult and child) per year is $0.55 per person, the income gained from work days lost from avoided illnesses is $0.68. The cost of productive parent days lost avoided from child illness is $0.26. This results in a total yearly household earnings potential from health gains of $5.59 per household per year.

Health Sector Savings

Using data based on the incidences of illness and health impact described above, estimated annual savings to the health sector per household at **$10.17**.

Education Potential

Education potential was estimated using 1) missed school days due to waterborne illnesses (using data generated above) and 2) missed school days by female children involved in water collection (using estimates based on time opportunity costs. The total estimated school absenteeism for a household of 5 is 2.24 days per year.

[11] Hunter, P., Zmirou-Navier, D., and Hartemann, P. (2009). "Estimating the impact on health of poor reliability of drinking water interventions in developing countries." Science of The Total Environment, 407(8), 2621-2624.

[12] Hutton, G., and Haller, L. (2004). "Evaluation of the Costs and benefits of water and sanitation improvements at the global level." World Health Organization, Geneva.

Overall Impact

After calculating the costs above, we make the general assumption that NextDrop will reduce costs in each of these areas by 50%. The appendix includes more detailed summaries of the final calculations.

Acknowledgements

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Appendix

Comparative Study of SMS and IVR Interfaces

As described earlier, we started our pilot by deploying a purely SMS-based system to receive and verify information from end users. We noticed usability issues with misspelling of words and a hesitance to send SMS in English. We then tried a Wizard of Oz voice-based system, which was more successful. This motivated us to build a fully automated Interactive Voice Response (IVR) application to perform the same tasks. In this section, we present a study comparing the two systems which helped us make a data driven decision on which system to continue using.

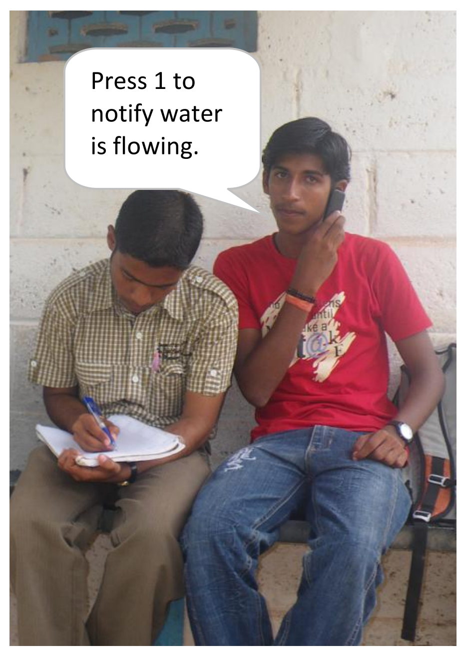

Figure 2When sending a notification with the IVR system, the user is presented with a prompt spoken in the local language.

Evaluating SMS and IVR Interfaces

We chose to focus on specific tasks of the system because the water for each valve area is only turned on once a week and we could not run an end-to-end test comparing the IVR and SMS implementations.

Subscription/Notification

We conducted a within-subjects controlled usability study on the SMS and IVR systems with 33 participants in Hubli (23 male and 10 female). We required each user to be a current subscriber in the NextDrop system. In addition, we further restricted our experiments to users who regularly used SMS.

Before the experiment, we explained what NextDrop is, and what the terms “subscribe”, “notification”, and “unsubscribe” are. Even though the users had signed up to use NextDrop, it was likely that they would not be familiar with all the elements of the system and we found it useful for them to have a model of how the system worked.

We then explained we had two systems – one SMS and the other voice-based – and were testing to see which one was easier to use. We stressed that there was no right answer and that they were not being graded. Since the participants were using their own phone, we gave them Rs. 20 (about 0.50 USD). This would compensate the costs of sending SMS and making phone calls and for their time.

After explaining the system, we gave them 3 tasks to complete: subscribe to the NextDrop service, notify that water is flowing, unsubscribe from the service. Each series of tasks was to be completed once on the IVR system and once on the SMS system. The order of systems was randomized to reduce priming effects. For each task, we measured the time to completion, the number of errors, and whether the user was able to successfully complete the task.

In addition to objectively measuring time and error rates, we asked each participant to fill out a brief survey. The survey asked each user which system they liked better and reasons for preferring that system. We also collected basic demographic information.

Verification

To test the response rate of verification requests we also conducted a between-subjects experiment of SMS and IVR systems. We again used current NextDrop subscribers. We randomly divided the 179 families into 2 groups, one for SMS and IVR, and further broke each group into 2 subgroups, one for morning and afternoon. For each group, we sent an SMS, or made a voice call and asked them to verify water availability. We collected data on how many people responded, what their response was and how many errors they made. We conducted the experiment when no water was available in the selected valve areas, so all responses should be negative.

Results

Subscription/Notification

For the subscribe, notify and unsubscribe tasks, SMS had mean task completion times of 66.84 s, 59.67 s and 54.97 s respectively. It was 62.09 s, 37.21 s and 33.39 s respectively for IVR (**Error! Reference source not found.**). With the hypothesis that the mean time for completion is lower for the IVR system, a matched t-test showed that the results are highly significant ($p < 0.01$) for the notification and unsubscribe tasks, but not significant for the subscription task.

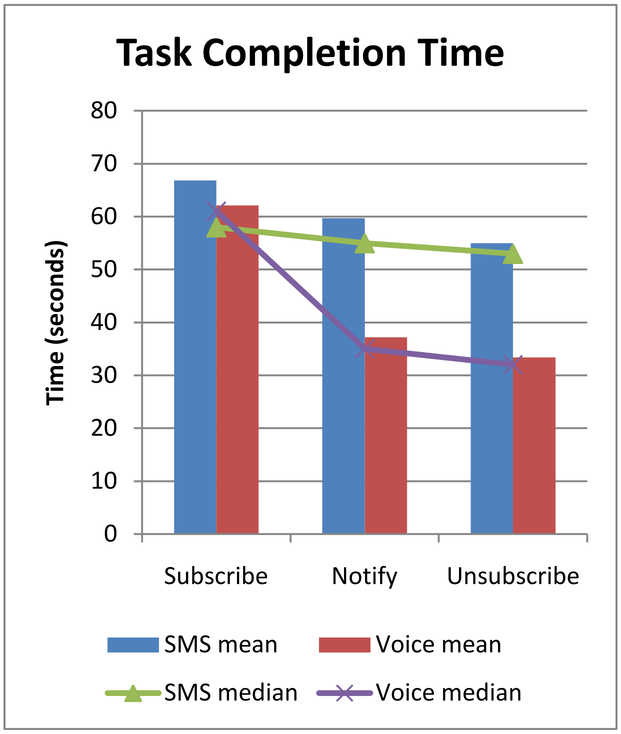

Figure 4 Task completion times. Users completed tasks faster using the voice system.

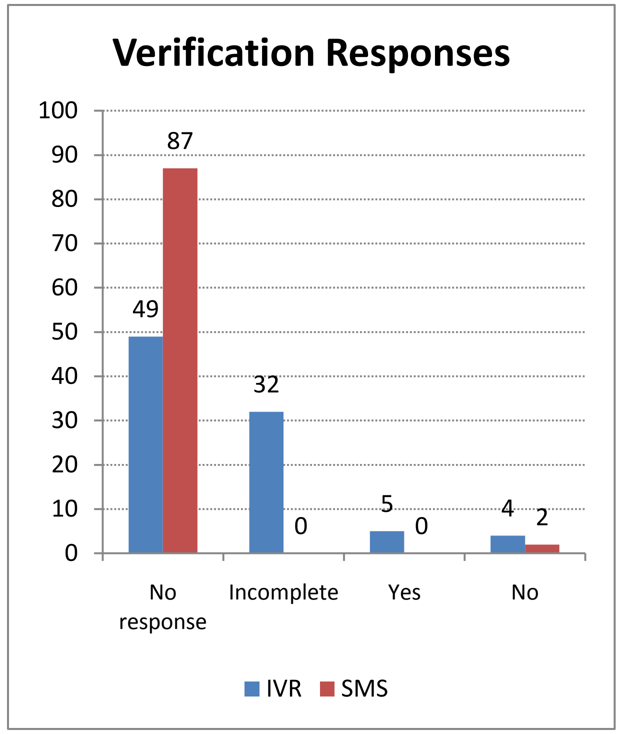

Figure 5 Comparison of verification responses using the IVR and SMS versions of NextDrop.

We recorded 4 errors in a total of 99 SMS tasks. All of them were related to misspelling of the SMS keywords that had to be used. No errors were recorded in the use of the IVR system. Of the 33 participants, 21 preferred the IVR system, 11 preferred the SMS system and one said she was equally comfortable with both.

Verification

We ran the between subjects experiment on a Wednesday, at 10 AM for the morning group and at 3 PM for the afternoon group. We did not see any significant differences in results between the two groups. **Error! Reference source not found.** shows the result of the test. For the 89 SMS verification requests, we received 2 responses, one of them not to the number we had mentioned in the SMS, but to the mobile phone of the operator we use for the Wizard of Oz voice system. We provide a hypothesis for this very low response rate in the discussion section. For the 90 IVR calls, we did not receive a response in 48 cases, 42 people responded, of which 26 hung up immediately, 9 provided a valid response (either Yes or No) and 7 provided an invalid response (pressed invalid number).

In Figure 4, users in the *No response* category either did not pick up the phone call or did not send an SMS back. Users in the *Incomplete* category for IVR picked up the call, but could not successfully complete the verification. For the SMS users, they returned the SMS but did not enter a message that was recognized.

In the case of the IVR system, we also found that more users indicated that water was flowing in their homes even though it wasn't. We think this is because of the way the voice message was phrased. It translated to "Is water flowing in your home?", which for someone without the NextDrop context in mind could be misconstrued, especially if they have water storage facilities at home. We plan to make the question more explicit that we are referring to supply from the water board in the future.

Discussion of Results

Subscription/Notification

21 of 33 users in our sample preferred the IVR system over SMS. The common reasons given were that it was easier to understand what they had to do in the voice-based system and that it took time to type an SMS while remembering the English keyword to be used. Having the voice-based system in the local language helped. Participants also noted that they liked the immediate feedback to an action in the voice-based system. In contrast, they had to wait for a response in the SMS system. Some participants preferred the SMS system because they felt it is more convenient and faster, especially if there were in an environment where they did not want to disturb others.

We found that 12 of the 33 participants had phones with local language support for SMS, 19 did not and 2 were not aware. While this is an improvement, the support for local language SMS on phones and telecom networks is still spotty. It is also not possible to determine support for local languages remotely via SMS, making it difficult to build robust systems that support them.

Verification

Overall, more users in the IVR system successfully responded to the call. We believe there are several possible explanations for this. One is the reliability of SMS delivery in the mobile networks. Past studies have shown that SMS delivery rates usually hover around 70-80% [13]. Additionally, because of spam SMS, many people have become desensitized to messages they receive from unfamiliar numbers. We plan to study this further.

[13] Thejovardhana S. Kote, S.R Jeyashanhker, Leena Chandran-Wadia. A large scale publish-subscribe platform for information delivery to mobile phones. In Comsware '08: The Third International Conference on Communication System Software and Middleware, 2008

While more users picked up the IVR call, many users immediately hung up without actually verifying water availability. We hypothesize that this was due to lack of familiarity with NextDrop. Even though all users voluntarily signed up with the system, we believe that many users forgot about the system and the incentive structure.

Based on the results of the study, we decided to use an IVR interface for any interaction with an individual, irrespective of whether it was initiated by NextDrop or the individual. We use SMS for all broadcast messages because it is both faster in getting the message out to lots of people and cheaper from a monetary perspective.

Partners

Deshpande Foundation: The Deshpande Foundation is a foundation based in Hubli that focuses its work on the "Sandbox," five districts in northern Karnataka, and promotes innovation and social enterprises for local organizations.

Karnataka Water Board: The Karnataka Water Board is in charge of supplying the cities of Hubli-Dharwad with water, from the source, treatment, distribution system, and operation and maintenance.

Hubli-Dharwad Municipal Corporation (HDMC): The HDMC is the municipal corporation that has outsourced the water supply to the Karnataka State Water Board. Since they are the original contractors for work of the Karnataka Board, it would be beneficial to share both data and feedback with HDMC.

Social Impact Calculations

Demographic Data and Frequency of Water Delivery: Throughout the analysis, we use the poverty line wage per year based on 2006 census survey data from Hubli-Dharwad as a proxy for opportunity cost. The poverty line wage of Rs. 17,500 per year, based on a six day work week, translates to a daily wage of Rs. 56 per day or $1.20USD. While the poverty line wage is a reasonable proxy many people in our target communities may command higher wages, so this is a lower bound.

Basic Demographic Info [Source: CMDR 2006]	
poverty line wage/year	17500
% population under age 15	0.234
% population over age 15	0.766
# people per household	5

To model the present unreliability of water in our target cities and consequent costs, we use data from a 2006 HDMC survey, which compares days between water delivery to the actual schedule:

Reported frequency of water delivery by households (Hubli-Dharwad Municipal Corporation in 2006 reported a rotational schedule of 4 days)		
Days between water delivery	% of households receiving [CMDR]	# collection cycles per year (days in a year divided days between water delivery
3	29.75	122
4	63.64	91
5	3.6	73
6	0.75	60
7	1.92	52
8	0.34	45

Time Opportunity Cost:

- Water delay by one day beyond the printed schedule of 4 days corresponds to an opportunity cost of one day of lost income at daily poverty line wage (i.e., if water comes every 5 days instead of 4, it is assumed that household lost a day of time in waiting).
- One adult per household loses potential earnings waiting for water.

Days lost per year per household	7	The sum of each % of households receiving at days > 4 multiplied by times/ years this occurs
$ lost per year per household	$8.93	Days lost multiplied by 1 day minimum wage
$ lost per quarter	$2.23	

The calculations above are based on city-wide unreliability; however, in our financial model, we assume only 60% of households will use NextDrop. The group of households that do select the service are likely to have uniformly higher rates of unreliability in water, which biases our estimates downward.

Averted Cases of Diarrhea: Hunter et al (2009) calculated the risk of disease due to unreliability of water in a system that otherwise provided high quality water based on the number of days per year an individual drank a lower quality source; NextDrop services would allow consumers to ration water more appropriately and save higher quality, treated municipal water for drinking purposes.

Probability of infection from drinking raw water [14]								
# Days/year drinking 'raw water':	1	2	3	4	5	6	7	0
Enterotoxigenic *E. coli*	0.128	0.24	0.337	0.422	0.496	0.56	0.616	0.001
Cryptosporidium	0.791	0.888	0.94	0.968	0.983	0.991	0.995	0.611
Rotavirus	0.982	0.997	1	1	1	1	1	0.872

The table above, demonstrates that for a population of 1000 people all drinking 'raw water' quality instead of treated water, there would be 128 cases of *E. coli*, etc. while the last column shows the situation with no unreliability: the intervention's impact is the difference between these two numbers. This is assumed to happen once per month. This yields an estimate of the cumulative adult and child cases averted by not drinking groundwater.

- Adult cases averted per year (cumulative): 0.2729
- Child cases averted per year (cumulative): 0.0834

Direct Patient Cost: Data for averted health-related costs was calculated using the World Health Organization cost-effectiveness procedures and data [15]

Transport cost per incidence of illness ($.50 per incidence and half the population uses transport)	$0.25
Ambulatory / day	$0.50
Hospitalization / 5 day	$10.00
Ambulatory rate	0.918
Hospitalization rate	0.082
Days off of work / adult episode	2
Days a parent takes off / child episode	5
% of min. wage as opportunity cost for caring for sick child	0.5

Yearly direct patient costs averted (adult and child) /year	$0.5447	The total number of cases of illness multiplied by the transport cost plus the ambulatory rate times cost of ambulatory visit and the hospitalization rate times the cost of hospitalization visit.
Income gained from work days lost from avoided illnesses	$0.6802	The number of cases of adult illness multiplied by days off of work per adult episode multiplied by the minimum daily wage.
Cost of productive parent days lost avoided from child illness	$0.2597	The number of cases of child illnesses multiplied by the days off of work per child episode times 50% of the minimum daily wage.
Yearly household earnings potential	$5.5883	Each of the above costs multiplied by the

[14] Hunter, P., Zmirou-Navier, D., and Hartemann, P. (2009). "Estimating the impact on health of poor reliability of drinking water interventions in developing countries." Science of The Total Environment, 407(8), 2621-2624.

[15] Hutton, G., and Haller, L. (2004). "Evaluation of the Costs and benefits of water and sanitation improvements at the global level." World Health Organization, Geneva.

from health gains		corresponding number of household members affected
Quarterly household earnings potential from health gains	$1.3971	

Assumptions:

- Household members are affected differently by each time. The whole household (5 members) is affected by direct costs due to illnesses; only adult members are affected by (3.83, based on demographic proportions of adult/children); and 1 household member is assumed to be affected by lost income due to caring for an ill child.

Health Sector Savings:

Data from [Hutton and Haller 2004, pg 18-20] for costs to health sector:

Cost/visit (low end) to the health sector	$4.30
Hospitalization days	5

Multiplying the total cases by the rates of health service by the costs and length of stay yields:

Yearly Savings per population	$2.03
Yearly Savings per household	$10.17
Quarterly Savings per household	$2.54

Education Potential:

Assumptions: Female children miss 1/4 of the time which would otherwise be spent at school or studying to collect water (this is an assumption, as this sector lacks evidence of the influence of water collection on girls' schooling). [16]

school days absent/episode	3	[Hutton and Haller 2004]
sex ratio	0.48	[CMDR 2006]
ratio of time missed	0.25	Assumption

The averted days of school absenteeism for the child population is calculated using the days saved due to illnesses added to the days saved for female water collectors. This is calculated for households of 5, assuming the child/adult ratio of the general population.

days of school absenteeism for child health	0.25
days of school absenteeism for female water collectors	0.20
Yearly school absenteeism for a household of 5	2.26

[16] Ray, I. (2007). "Women, Water, and Development." Annual Review of Environment and Resources, 32.

Social Return on Investment

	Year 1		Year 2		Year 3		Year 4		Year 5	
Quarter	2	4	6	8	10	12	14	16	18	20
Total number of cities operational	1	1	2	2	4	8	14	22	33	50
Cumulative Number of Households Served	15,000	42,000	75,000	104,727	147,955	247,909	461,864	801,273	1,273,636	1,949,864
Social Benefits										
Opportunity Cost Benefits from Time Savings	$16,743.79	$46,882.61	$83,718.95	$116,902.10	$165,154.66	$276,729.18	$515,556.52	$894,422.82	$1,421,699.99	$2,176,540.49
Opportunity and Direct Cost Benefits from Health	$10,478.09	$29,338.66	$52,390.47	$73,156.15	$103,352.11	$173,174.32	$322,630.04	$559,720.73	$889,685.44	$1,362,056.97
Health Sector Savings	$19,070.36	$53,397.02	$95,351.82	$133,145.81	$188,103.13	$315,181.10	$587,193.83	$1,018,704.15	$1,619,247.24	$2,478,973.91
Education Potential (missed school days averted)	4,236	11,860	21,178	29,572	41,779	70,004	130,419	226,260	359,644	550,595
Total Social Benefits	$46,292.25	$129,618.29	$231,461.24	$323,204.06	$456,609.90	$765,084.60	$1,425,380.39	$2,472,847.71	$3,930,632.67	$6,017,571.37
Total Operating and Capital Costs	$33,700.00	$34,600.00	$45,500.00	$46,490.91	$69,531.82	$114,063.64	$205,395.45	$298,009.09	$471,454.55	$667,495.45
Social Purpose Benefit Flow	$ 12,592.25	$ 95,018.29	$ 185,961.24	$ 276,713.15	$ 387,078.08	$ 651,020.97	$ 1,219,984.94	$ 2,174,838.62	$ 3,459,178.13	$ 5,350,075.91
Discount Rate										
Discount Factor	0.93	0.87	0.81	0.76	0.70	0.66	0.61	0.57	0.53	0.50
NPV of Social Benefits	$ 15,990,641.80									
NPV of Project Costs	$ 2,153,199.32									
Benefit-Cost Ratio	7.426456841									
Social Purpose Value	$ 13,837,442.48									