Using CAM-equipped Mobile Phones for Procurement and Quality Control at a Rural Coffee Cooperative

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ABSTRACT

With globalization, small rural producers must compete in a competitive economic market. Due to their small size and limited financial capacity, they face significant challenges in doing so. We discuss the design and evaluation of two mobile phone based tools to help small producers achieve economies of scale and a quality premium. These tools were developed using CAM, a camera-based mobile phone application framework specifically designed for the rural developing world. CAM DPS (Delivery Processing System) efficiently captures transactions between producers and cooperatives, in order to monitor remote inventory levels, and document the price paid to the producer. CAM RANDI (Representation AND Inspection tool) allows local inspectors to digitally capture the condition of farm parcels, using a combination of paper, text, audio and images. Using this data, rural producer cooperatives can improve their efficiency and monitoring, and ensure conformance with quality and certification standards. A preliminary evaluation suggests that these applications are accessible to target users and will serve a significant need.

Keywords

mobile phones, paper user interface, rural development, ICT, cooperatives, agriculture

1. INTRODUCTION

With globalization, small rural producers must compete in an increasingly competitive economic market. Due to their small size and limited financial capacity, they face significant technical and operational challenges in doing so. Deficits in infrastructure and planning capacity increase their transaction costs when compared to larger producers. To counteract this, small producers can try to avail a quality or brand advantage — by highlighting specialized production techniques (such as organic or bird-friendly cultivation), geographic specialization and social capital. However, the lack of physical infrastructure, enforceable production standards and efficient marketing channels limit these advantages, causing small producers to continue to sell at commodity prices.

The global coffee market is an acute example. Coffee is now the second most traded commodity in the World - trailing only petroleum. However, rural small producers have not benefited from the increase in coffee trade and consumption. One reason is a corresponding increase in production. In the early 1990s, Vietnam started producing coffee. Coinciding with an increase in Brazilian coffee production, the market was flooded, and worldwide coffee prices fell sharply. As a result, growers in Latin America, facing higher production costs (but growing better coffee), were decimated [5].

Responding to this crisis, there have been several efforts to help small coffee farmers around the World earn a living wage, and capitalize their quality advantage and sustainable growing practices.

Fair Trade: Fair Trade certification seeks to improve the living condition of marginalized producers by creating consumer awareness, promoting change in trading practices and empowering producers to play a larger role in the marketing and sale of coffee [11]. Certifying agencies monitor producer organizations' labor and environmental practices. Coffee farmers are guaranteed a minimum price of $1.26 per pound, or $0.05 above the current international market price, whichever is higher. Fair Trade also encourages the establishment of direct relationships between coffee importers, roasters and producers.

Organic Agriculture: According to the International Federation of Organic Agriculture Movements (IFOAM), organic agriculture is an attempt to *sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings* [7]. Actual requirements for growing organic produce vary from country to country. One priority is on reducing the use of chemical fertilizers and pesticides. Organic certification agencies perform farm inspections to assure quality and prevent fraud.

Bird-friendly: Bird-friendly certification ensures that native shade trees are retained on coffee parcels, preventing sun damage and soil erosion and providing shelter to migratory birds that in turn are a natural insecticide [17]. Originally, all coffee was shade grown, until a sun-resistant hybrid was developed to maximize the amount of cultivable land. This hybrid has replaced 17% to 69% of the total coffee cultivation in different countries, severely impacting the migratory bird population. Bird-friendly certification was introduced in 1996 to address this problem.

The idea behind each of these certifications is that consumers will pay a premium for certified products meeting ethical and environmental standards. However, *monitoring* - ensuring that producers are conforming to standards, and *marketing* - conveying the "story" behind the certification, are both significant challenges faced by these and similar efforts.

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Figure 1: Barillas from the sky

1.1 Mobile Phones and CAM

Mobile phones, due to their small size, affordability, familiarity, wireless connectivity and limited power consumption, present an ideal hardware platform for rural conditions. Mobile phones have already been demonstrated to improve the market performance of small rural producers in some contexts [9].

CAM is a mobile phone software platform for rural developing world applications [16]. Supporting minimal, paper-based navigation, a simple scripted programming model and off-line multimedia interaction, CAM is uniquely suited for rural computing requirements. Users navigate CAM applications by capturing bar-codes printed on paper forms using the mobile phone's built-in camera, or by entering numeric strings. Forms-based data entry is extremely common in the developing world. CAMForm analogs of existing paper forms serve as offline clients for CAM applications. CAM provides an API for accessing the mobile phone's user interface, networking and multimedia capabilities. Data can be transferred immediately when the phone has a network connection, or later, using asynchronous (SMS, MMS and e-mail) and/or physical networking protocols.

We have developed, evaluated and deployed a CAM application for capturing data from microfinance groups in rural India [15]. In this paper, working with Asobagri, a coffee cooperative based in Barillas, Guatemala, we discuss the design and evaluation of two CAM applications for automating procurement and farm monitoring at a rural coffee producer cooperative.

1.2 Asobagri: The Coffee Cooperative

Asobagri was founded in 1989 in Barillas (Figure 1), a city in the Guatemalan highlands with a population of about ten thousand people. Barillas is accessible only by unpaved road, helicopter or small airplane. The nearest major city is Huehuetenango, 8 hours away on the local bus. Barillas' urban zone has cellular coverage and Internet access.

Asobagri is a producer/exporter cooperative. Namely, Asobagri is responsible from soil care and seeding until the *oro* (unroasted coffee beans) leaves the port on its way to one of their five customers in North America, Europe and Japan. Asobagri's coffee carries four different international certifications: FLO International's Fair Trade certification, OCIA International's Organic certification, JAS' Organic certification and Bird-friendly certification.

Asobagri's main goals are to provide market access to over 800 small coffee producers of the Barillas region, support education amongst its members, ensure farmers a living wage (in accordance with Fair Trade) and to promote maintenance and respect for the environment. The staff that work at Asobagri's office are primarily college-educated. The coffee producers themselves live in the remote, mountainous areas around Barillas, where there is often no electricity or phone coverage. Many are illiterate. In some villages, many family members have moved to the United States (perhaps illegally) in order to provide additional income for their family.

We have designed, developed and evaluated two prototype CAM applications for automating Asobagri's procurement and farm monitoring processes. The first application, CAM DPS (Delivery Processing System), allows the cooperative to accurately and efficiently capture coffee deliveries and payments to farmers, even in a mobile context or in areas with limited infrastructure and connectivity. The second application, CAM RANDI (Representation AND Inspection tool), allows farm parcel inspectors to gather multimedia data based on a multiple-choice questionnaire. The results are used to monitor production techniques and compliance with certification requirements.

The rest of the paper is organized as follows: Section 2 discusses related work. Section 3 presents the design, evaluation and current status of the prototype CAM DPS application. Section 4 presents the design, evaluation and current status of the prototype CAM RANDI application. Section 5 discusses plans for future work and concludes.

2. RELATED WORK

In this section we discuss previous IT systems that address agricultural procurement, extension, inspection, certification and marketing in a developing world context.

2.1 Procurement

Agricultural procurement refers to the collection and processing of deliveries from individual producers. Akashganga is a project that automates the milk collection process at dairy cooperatives in India [18]. A digital scale is connected to a PC that maintains local transaction records and prints payment slips. The Warana Wired Village project implemented a system for sugar cane farmers in the state of Maharashtra, India [3]. Farmers are equipped with smartcards allowing them to register their property, obtain permits, process payments, access their funds and purchase fertilizer at 54 PC-based village information kiosks. eChoupal is another Indian effort implemented by ITC-IBD, the agri-business division of ITC. By visiting the eChoupal information kiosk, farmers can find out the current price of soy at various markets and, if they choose, sell directly to a local ITC-IBD representative — reducing their transaction costs and maximizing their revenue. JAMEX is a network of "chill centers" distributed across Jamaica [14]. Chill centers are procurement and storage locations for farmer-supplied produce. An integrated IT solution coordinates delivery, storage, transport and sales to customers.

2.2 Extension

Agricultural extension refers to the transfer of agricultural (and other) knowledge to farmers through various kinds of communication and learning activities. Finctrac implemented a system in Honduras where extension workers were equipped with a GPS device, laptop, digital camera, portable printer, cell phone, portable weather station and a floppy disk drive [13]. Extensionists are able to access location-specific agricultural information, provide immediate technical advice to farmers and track their extension activities. AGIS is a PC-based system implemented in South Africa that allows extension workers to access a geo-referenced database with physical, social and economic information essential to agricultural planning and decision making. An electronic question and answer system to allow extensionists to communicate with agricultural scientists and researchers is in development [19]. eSagu is a research system developed at IIIT Hyderabad. Extension workers are equipped with a digital camera to document farm conditions and current problems [2]. Using a PC-based kiosk, they submit text and image reports to agricultural experts at a central location. Later, they download advice to be conveyed back to farmers.

2.3 Inspection, Certification and Marketing

e-cert is a commercial field monitoring and certification system using a Tablet PC to perform field inspections [4]. A separate database application provides for the creation of inspection templates, scheduling of inspections and management of data. A group of UK food retailers developed the Social and Economic Development Exchange (SEDEX), a web-based tool used to track and audit labor standards along the wine, fruit and cut-flower supply chain [12]. ACTRES is another web-based system that allows flower growers to share information about their water and energy consumption, use of fertilizers and waste generation [10]. This is used to ensure compliance with certification requirements, and for growers to track their own use of natural resources. QualCheck captures quality assurance data during the processing, packaging, storage, distribution and serving of food and agricultural products [1]. Utzkapeh, an independent certifier of ethical and sustainable coffee, has developed its own web-based system to track certified coffee through the supply chain from producers to consumers [21]. Anacafe, Guatemala's coffee trade association, has developed a web portal to document the geographic specialization of coffee growing regions and to provide an Internet presence for small coffee producing organizations [6].

3. CAM DPS: DELIVERY PROCESSING SYSTEM

3.1 Current Delivery Process

During harvesting season, producers bring their coffee quintales to the Asobagri office to receive their payment check. When the office opens at 8AM, there is often a line of farmers waiting with their coffee. They would have started the arduous journey from their villages hours earlier, sometimes even the previous day.

Before producers can receive payment for their coffee, they have to go through several steps, illustrated in Figure 2. First, the producers need to register in a paper notebook, and wait until the person in charge of data entry is ready to enter their information in the computer. An Excel spreadsheet is used to record producer deliveries and payment amounts. After this information is entered, the coffee's

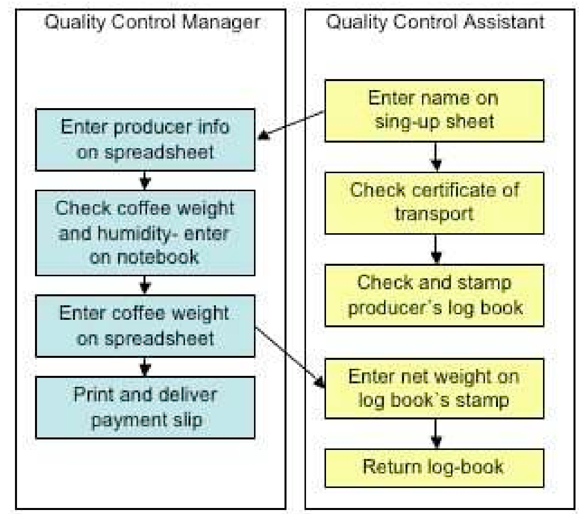


Figure 2: Asobagri's delivery process flow chart

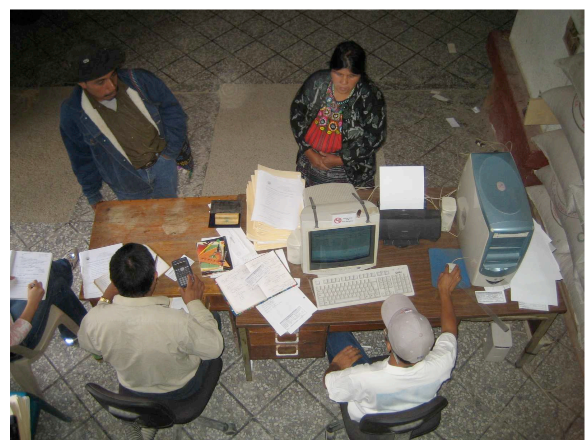


Figure 3: Configuration of Asobagri's delivery processing desk

weight and humidity is checked. This is also entered in the spreadsheet. The producer's log book is stamped, indicating the delivery's weight and net price to be paid to the producer. Finally, a payment slip is printed. The producer takes the payment slip upstairs to the accounting department and waits to receive his check.

Meanwhile, a second identification slip is handwritten, the coffee quintal is sewn shut and the identification slip is attached to it. This label provides a way to know, for each quintal of coffee, what kind of coffee it contains and which producer and land parcel it came from. When the coffee is later organized into lots and shipping containers for export, the entire lot is identified solely by the lot number - indicating the source coop (Asobagri), state (Huehuetenango), and a categorization of the coffee based on the altitude where it was grown (hard, semi-hard or strictly hard). The cooperative internally maintains a record of specific deliveries corresponding to lot numbers, conforming to international traceability regulations on food products [20].

Delivery processing is one of Asobagri's most inefficient and business limiting procedures. At busy times of the sea-

Figure 4: Repeated manual entry of the same information - a payment receipt (top left), quintal label (top right) and payment slip (bottom)

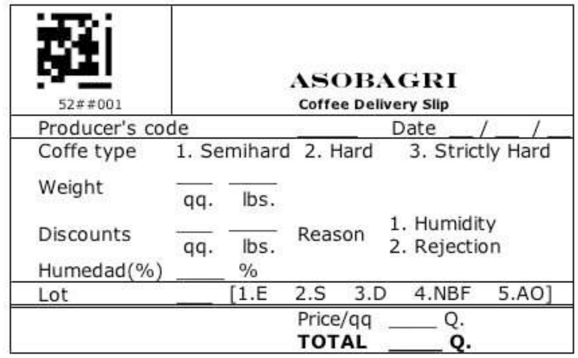


Figure 5: CAMForm delivery receipt. A single barcode click prompts the user to enter the information from the receipt, accompanied by audio and textual prompts.

son, the delivery process can take up to three hours for an individual farmer (including the time spent waiting in line). This could mean having to spend another night in the city, incurring extra expenses and losing out on a day's work.

One source of inefficiency is repetitive data entry. Each producer's identifying information is hand-recorded three times: on the payment slip, payment receipt and on the label for their quintal (see Figure 4). The existing automation tools (Excel spreadsheets) are used inefficiently. Three spreadsheet formats are maintained, each a different view of the same data. Some potentially useful information, such as the reason for rejecting a coffee delivery, is not captured at all.

Another limitation faced by Asobagri is storage space. Asobagri can store four to five distinct coffee lots in its current warehouse in Barillas (in fact, the last lot limits access to the office bathroom, forcing employees to "hold it" until after the growing season). These are assigned to different types of coffee, classified by altitude and certification requirements. Lack of space limits further differentiation, and the corresponding ability to maximize revenue by attracting premiums on its highest-quality coffee.

Asobagri is planning to build more storage points closer to producer farms. This will increase the total storage space and potential for differentiation, and also drastically reduce farmer costs in delivering coffee. However, due to limited infrastructure (power, network connectivity, shelter, etc.), Asobagri's current PC-based delivery processing tool is unsuitable for such locations. A mobile phone-based tool would be more appropriate for these conditions.

3.2 Prototype Design

We developed a CAM-based mobile delivery processing tool based on the design of existing paper artifacts and extensive discussions with Asobagri's management, staff and members. Our goal was to provide a tool that could aggregate the information from each delivery into a database, from which labels and reports could be printed. Similar applications are used in the supply chains of commercial retailers and transport specialists. However, these employ proprietary hardware, software and support services that make them all but inaccessible to small, developing world businesses.

The resulting CAM delivery receipt is shown in Figure 5. The receipt contains the producer's code, the current date, the type, weight and humidity of the coffee, the amount of coffee rejected (or purchased at a discounted price), the reason, the assigned lot number, the price paid per quintal and the total price paid. Each receipt has two carbon copies - for the delivery and accounting records respectively. The original is given to the producer for their own records.

During the delivery process, the paper receipt is filled out. Then, the delivery copy of the receipt is entered using CAM. A single click of the barcode with the camera prompts the user to enter each of the data fields from the receipt in sequence, accompanied by a text and audio prompt for each field. As Asobagri's weight scale can only hold four quintales at a time, there can be several weight entries per delivery slip. This is supported by looping through weight entry prompts until the user enters a zero, indicating the end of the sequence. To edit the entered data, the data entry operator simply clicks on the barcode again, re-playing the prompts.

After all the data has been entered, the user is prompted to send it to the server application. This can be done via an HTTP query or a SMS message. SMS can be used if the network connection is weak or inconsistent, or if the mobile service provider does not provide Internet connectivity. The data message is received by a mobile phone at the Asobagri head office that is connected by bluetooth or by physical cable to a gateway application running on the server computer. Instead of SMS, data can also be physically transferred using the mobile phone's built-in memory card. This card is brought to the head office and inserted into a card reader. The data is then extracted and processed by a server-side script. Thus far all these options are hypothetical, as we have not developed the server-side software for the DPS application.

3.2.1 Potential Advantages

The delivery tool seeks to alleviate the challenges mentioned in the previous section by:

- Consolidating data entry in one paper slip. This will speed up producer throughput during the peak harvesting season. Labels and other reports are printed automatically, reducing manual data entry.

- The reduced infrastructure requirements of mobile phones allow for mobile / remote delivery points. Providing delivery points close to producer farms is a noted best practice for rural producer cooperatives [8].

3.3 Preliminary Evaluation

In this section we describe a preliminary evaluation of CAM DPS. We compared the efficiency and accuracy of this tool to an equivalent Microsoft Excel format (simplified from the existing version).

Participants: All five of our study participants were office staff of Asobagri, and were familiar with the current delivery processing system. Including four males and one female, their age ranged from 22 to 44, with a mean age of 29.6. All had at least a high school education, and moderate experience with mobile phones, computers and Microsoft Excel. None had used CAM before.

Experimental Design: We measured the execution time and error rate for entering and submitting ten delivery slips in sequence. The slips were pre-populated with realistic quantities collected from a sample day at Asobagri. For the CAM version, we used a Nokia 6600 phone running the CamBrowser application. For each slip, the user captured a single barcode and entered the necessary data as prompted. Each prompt consisted of a message on the screen accompanied by a short audio description, both in Spanish. All data entry was numeric, with the exception of the producer ID, which was captured as a barcode located on the reverse of the producer's Asobagri membership card.

The entered data was stored in a text file on the phone. After each test, this was reviewed to determine the number of errors. Execution time was measured by an observer with a stopwatch, from when the user focused the phone camera on the first form until the last value for the tenth receipt had been entered. Each user performed the same task using an Excel spreadsheet on a PC. The same delivery slips and written values were used. The only difference was that in the PC version, the user had to manually enter the producer ID. The order of the two variations was counter-balanced.

Before starting, the use of the application was explained and demonstrated to each of the users, and they were given time to practice until they felt comfortable with both systems. After the test, the participants completed a short questionnaire assessing the ease of use of each version and for gathering other subjective feedback.

P.	**Excel**		**CAM**	
	time	error	time	error
1	28.85	0.2	66.87	0.2
2	39.97	0.4	42.41	0.0
3	55.13	0.1	65.35	0.0
4	38.06	0.1	38.61	0.1
5	48.10	0.0	70.10	0.1
mean	42.02	0.16	56.67	0.08

Table 1: The mean execution time and number of errors per delivery slip for each participant with the Excel and CAM variations.

Quantitative Results: As shown in Table 1, the average execution time was 15 seconds faster using Excel than CAM. However, the average number of errors was twice as high with the Excel version. Due to our small sample size, the p values are not significant.

Given that this was the users' first day using CAM, and that they were already familiar with Excel, it is expected that this average time difference would have leveled out over a period of a few days. This is supported by our earlier results in microfinance [15].

P.	**CAM**	**Excel**
1	4	2
2	2	3
3	2	3
4	1	1
5	2	3

Table 2: Participant's rating of the ease of use of each interface on a 1-5 Likert scale, with 1 being easiest.

Qualitative Results: As shown in Table 2, four out of five users found CAM either as easy or easier than the Excel version. Generally, the more familiar they were with the existing system, the faster they performed using Excel and the more comfortable they felt with it. For example, the one user that did find Excel easier to use had significant experience with the existing delivery processing system. Those users that did not use Excel on a daily basis felt more comfortable with the CAM version.

Participants liked CAM because it could be used without consistent power, as power outages are common in Barillas (usually once every three or four days). The form factor was also desirable, in that it could be used in mobile settings, without sitting at a desk. They also liked the audio prompts, with some users suggesting that this reduced errors. This is corroborated by our earlier experimental results, where a text-only interface resulted in significantly more errors then an audio-enhanced version [15].

One feature that was requested was an "undo" or "back" button that could be used when the user had made a data entry error. Currently, the only solution is to cancel the data entry sequence, and start again by clicking on the barcode. In the future, we plan to use the joystick on the phone interface to provide "back" and "forward" navigation.

3.4 Discussion

Our early results indicate that the CAM-based delivery processing tool can provide comparable performance to an Excel-based PC version. Given the mobile phone's other advantages in cost, utility and infrastructure requirements, it would be the clear choice for Asobagri's future remote/mobile delivery points, if not for the main warehouse itself. This observation was confirmed by Asobagri's current executive director and production supervisor.

In the future, we plan to test this system longitudinally, accounting for learning effects. We are also planning to fully implement the server-side of the system. This will consist of either developing or customizing an existing inventory management system, and connecting the CAM-based delivery processing tool to it. After this system is implemented and deployed, we plan to collect data regarding the impact on farmer waiting times and transaction costs, on system "uptime" (the time it is working and functional) and on the transparency, efficiency and profitability of the cooperative.

The CAM DPS system is flexible enough to connect to a variety of back-end systems. As a result, this tool can be used by any organization interested in monitoring inventory levels at storage warehouses or in documenting transactions between producers and cooperatives. For example, a Fair Trade certifying agency could connect the tool to its own back office systems, allowing it to monitor inventories and farmer payments around the World.

4. CAM RANDI: REPRESENTATION AND INSPECTION TOOL

4.1 Current Inspection and Monitoring Practices

Maintaining the quality and certification of Asobagri's coffee requires continual training, monitoring and inspection. The bulk of this work is carried out by *agricultural extensionists*. Asobagri has a staff of five part-time extensionists, each covering a distinct region. Extensionists are recruited from the ranks of producers. They live in the region, spending most of their time farming their own land parcels. Their role with Asobagri is to recruit, train and work with producers to produce high-quality, organic, bird-friendly coffee.

The extensionists travel regularly to monitor the progress of each producer's land parcels. Each producer keeps a log book where he records the agricultural activities he performs. The extensionist inspects this log book, and the land parcel itself, to make sure activities are being performed correctly. The extensionists go to the office in Barillas every two months to report to Asobagri's internal control manager, a coffee-growing expert, about their region's progress and issues.

Asobagri also has bi-annual internal inspections. These are in addition to the external inspections conducted by certifying agencies, and are used to ensure the producers' compliance with recommended practices and certification requirements. The internal inspections are conducted by a set of twenty inspectors that are experienced extensionists, staff and management of Asobagri. They are each assigned to regions some distance outside their own home area, to reduce the chances of bias and collusion. The overall inspection process can be seen in Figure 6. The process lasts two weeks, covering every parcel of every producer, with each inspector covering up to ten coffee parcels a day. This is a tremendous data collection task. Some parcels are more than three hours away from the road by foot, over rough terrain.

Currently, inspectors complete a three-page paper inspection form for each producer. Part of this form is completed while in the parcel itself, where they enter data such as the soil quality, coffee-tree quality, disinfectants used and crops grown on the neighboring parcels. All of these can have an impact on coffee quality and certification requirements. The inspector then visits each producer's processing area, including the depulper and/or washer, located either at their home or elsewhere, to document the various tools' presence and hygiene. At the end of the day, the inspector prepares a hand-written parcel report for each producer (see Figure 7). In this document, they detail mild and significant breaches of Asobagri's standards and certification requirements, and provide recommendations to correct the same.

During the inspection period, inspectors go back to the Asobagri office after each week to hand in reports and forms to be reviewed by Asobagri's internal control manager. If

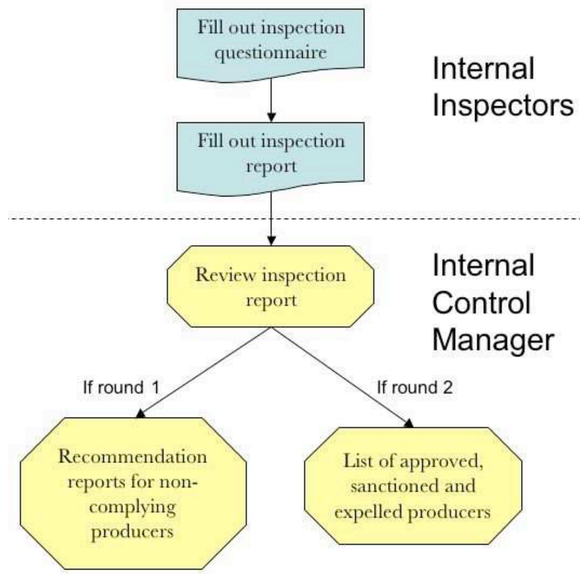


Figure 6: Internal inspection flow-chart

it is the first internal inspection of the year, the control manager will issue a final set of recommendations for each producer. These will be communicated back to the producer by their local agricultural extensionist, who will attempt to ensure their execution during future monitoring visits. If it is the second inspection, the control manager will make a list of producers to sanction or expel from the cooperative.

The main challenges faced in this process are:

- *Unsuitability of paper forms* Paper forms are not suitable for internal inspections because they are difficult to write upon and prone to get wet or dirty during visits to the parcels.

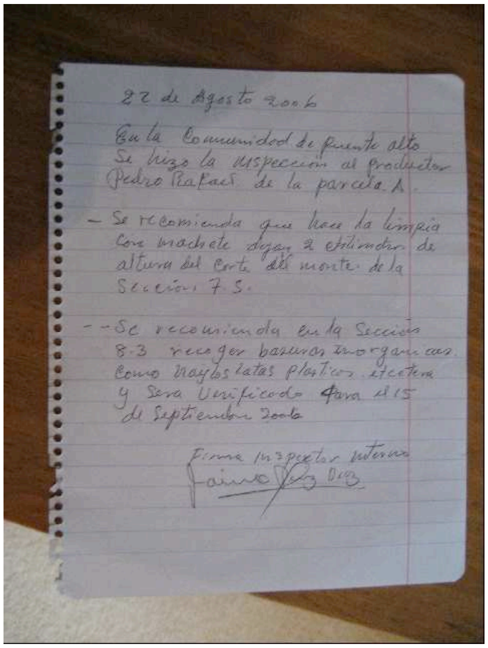
- *Evidence of inspection* Inspectors cannot visually document their presence on each parcel, and the breaches they have discovered. In cases of dispute, producers can allege that the breaches were fabricated by the inspector, or that the inspector was never there. Some inspectors may in fact skip parcels that are difficult to reach.

- *Breach of contract standards* There are no documented standards for mild and severe breaches, making the inspection reports subject to the inspectors' bias.

4.2 Prototype Design

RANDI is a mobile phone application that allows inspectors to capture multi-media inspection data using a CAM-enhanced version of the current inspection form. Inspectors can visually document breaches of Asobagri's certification and quality requirements and their physical presence on each parcel. They can also generate useful media content about individual farms and producers for Asobagri to display on its web site. Therefore, we call this tool *CAM RANDI* - the CAM *R*epresentation *AND I*nspection tool.

RANDI includes a small laminated booklet to guide the inspectors through the inspection process (see Figure 8).



22 de Agosto 2006

En la Comunidad de Puente alto
Se hizo la inspección al productor
Pedro Rafael de la parcela A.

– Se recomienda que hace la limpia
con machete dejar 2 centímetros de
altura del corte del monte de la
Sección 7.5.

– Se recomienda en la Sección
8.3 recoger basuras inorganicas
como vaso latas plasticos etcetera
y sera verificado para el 15
de Septiembre 2006

Firma inspector interno

Figure 7: A hand-written inspection report is prepared by the internal inspectors for each producer. It outlines mild and severe breaches of Asobagri's production standards and certification requirements.

Figure 8: Final design of the inspection booklet. Compact, laminated, rain and dirt-proof design allows inspectors to enter data directly on the phone, including relevant images and audio.

		90##10 record audio	91##10 take picture	80 Section 10
Section 10: Storage				
10.1	Do you have a storage room?			1. Yes 2. No
10.2	Do you have a platform in your storage room?			1. Yes 2. No
10.3	Are there risks of contamination with other products?			1. Yes 2. No
Immediate recommendations				

Figure 9: Part of the CAM-enabled inspection format - each section has its own "take picture" and "record audio" barcodes.

During our initial usability trials, we found letter-size paper forms cumbersome to carry up the steep inclines to the parcels, and also prone to get torn, wet or dirty. Moreover, entering data on paper was tedious under these conditions, and created unnecessary work for the inspectors. During an initial user trial, one of the inspectors suggested to stop writing on the paper form and to enter data only using CAM. After discussing this with the internal control manager, we agreed that a laminated half letter-size booklet supporting only digital data entry was preferable. The laminated booklet contains the full text of each question (important for questions that do not fit on the small mobile screen), and numeric options with their corresponding values for multiple-choice questions.

The booklet has eleven sections that are each accessed via a corresponding barcode on the booklet (see Figure 9). After clicking on the barcode, inspectors are prompted to answer each question in the section sequentially. Two more barcodes allow the user to capture images and audio recordings for each section. These are stored on the phone and tagged with metadata indicating the appropriate producer and section. For example, inspectors can capture images documenting an observed breach, or record an audio clip of their recommendation to the farmer. As in the delivery processing application, the identity of the producer is captured as a barcode image on the reverse side of their cooperative membership card. The inspector's physical presence on the parcel is documented by capturing a picture of himself, with the producer, on the specified parcel. Alternatively, we can also use a GPS or GSM tracker to confirm this information [8].

Asobagri's current paper inspection form contains a mix of open-ended questions, and questions that require a numeric or discrete Yes/No answer. Example questions include: the organic status of the coffee parcel, the number of fruit trees that are growing on the parcel, whether or not the producer has used a disinfectant for the coffee seeds and the percentage of soil covered by live matter.

In the CAM version, due to the difficulty of text entry, we converted the open-ended questions to multiple choice. This required iterating with staff and management to determine the set of possible responses to each question. Responses were now standardized across all of the inspectors. For example, instead of recording the organic status of the parcel as an open-ended text field, we asked the user to choose from the following options: 1) conventional, 2) natural, 3) organic and 4) in-transition. However, as we continued our testing, more and more possible options emerged for some of the open-ended questions. One solution was to allow the user to record an audio clip. For example, this is used for recording the recommendations made by the inspector to the farmer.

All of the captured data is stored on the phone's external memory card. When the inspections are completed, the

Figure 10: The inspection blog replaces the paper inspection form and the hand-written report. The blog can be indexed by producer ID, group ID, form section and type of breach.

inspectors go back to the office and transfer the data by removing the phone's memory card and inserting it into a USB card reader connected to a PC. We decided to adopt this kind of *physical networking* solution because of the limited cellular coverage and services in the region, and to save on connectivity costs [22]. It is not essential that the inspection data be transferred to the head office immediately, and the inspectors will have to return to discuss their observations with the control manager anyway. Under different conditions, it would also have been possible to implement remote data transfer using HTTP or a messaging protocol, like MMS or e-mail, and an appropriate gateway application.

After the data is downloaded to the PC, we run a script that processes the data, adds the corresponding tags (producer id, group id, section id and/or type of breach), and posts the result as a blog entry. Breaches are automatically classified according to rules specified by the Asobagri management. The internal control manager can browse entries on the blog by inspector, producer, region, form section or type of breach.

We use Wordpress as our blogging software, and Postie to automatically format the images and text for each post [23]. Wordpress provides many standard blogging functionalities, including embedding images and audio, allowing users to add comments, make new posts, edit existing posts and create new categories. While a blog does not provide the same functionality as a custom database application, and some views are not possible, this approach has thus far been sufficient for this application, and has required very little server-side development effort.

4.2.1 Potential Advantages

The challenges mentioned in the previous section are addressed by:

- Requiring the inspector to carry a mobile phone and a single laminated inspection guide (versus a 3-page paper form *per producer*) drastically reduces the weight of paper they must carry.

- Audio and image data allows the inspector to document breaches, recommendations made to the producer and their physical presence on the parcel more convincingly. This data can be used by the internal control manager and extensionists to better understand each parcel's status and to document best/worst practices.

- Providing discrete options for some questions, and a standard definition of mild and severe breaches, reduces the opportunity for bias in the earlier open-ended report format.

- Data captured during inspections can be used to create a visual history of each parcel, and to market Asobagri's products to potential customers, thereby building stronger producer-consumer relationships.

4.3 Preliminary Evaluation

In this section we present the results of a preliminary evaluation of the CAM RANDI tool. Our goal was to assess the impact of this application when compared to the current paper-based inspection process, both in the field, and also on the later use of this data by the internal control manager.

Participants: Four inspectors' were included in the evaluation. All were male. Their age ranged between 31 and 50, and their education ranged between 1st and 6th grade completion (with the exception of the internal control manager, who has a college degree). All the participants were experienced, certified inspectors who had been performing internal inspections for at least five years. All had previously used a mobile phone, but had no experience with CAM.

Experiment Design: We compared two inspections conducted using the RANDI tool, and two inspections conducted using a paper form. For consistency, the paper form had the same multiple choice questions as used in the RANDI variation, including additional space for open-ended comments. We gave the paper users a digital camera (Canon SD 500, 7.1 megapixel) and audio recorder (integrated in a Nokia 6235 model mobile phone) to use while conducting the inspection, to approximate the same functionality in RANDI and to assess the impact of the integrated forms-based CAM approach.

A between-subjects protocol was used, with different inspectors being tested with CAM and the paper-based version. Due to long travel times between producer communities, and the arduous climbs into the parcels themselves, we did not have enough time to conduct a controlled, within subjects experiment. Furthermore, it was difficult to maintain a sterile testing environment, given that the inspectors, and especially the producers and their families, were very excited to witness this new technology. During the inspections we visited, there were many people around, and the inspectors often got distracted, both with people and nature. They were roaming around taking pictures of spiders, beehives, fruits on trees, etc. While this was a distraction for our testing, we hope that this excitement carries forward when using the system in practice.

The inspections were conducted in two producer communities - *Palo Alto* and *La Palestina*. The RANDI users were first trained on how to use CAM and navigate the forms. For those using the paper forms, we allowed them to review and become familiar with the new format, and also taught them how to use the camera and audio recorder. All users were given time to practice until they said they were comfortable with the new tools. They then performed a full inspection of a parcel, completing eleven sections, taking pictures and recording audio whenever they saw fit. In the RANDI version, the inspectors were explicitly prompted to take three pictures (one each of the inspector and producer signing the inspection receipt, and one of the producer at the parcel), and to record one audio message (their final recommendations to the producer).

After conducting the inspection, we asked each inspector to produce a report, either by hand or using the RANDI blog tool (depending on which version they had used). We then asked the internal control manager to review these reports, and provide his feedback. At the end of the evaluation each participant completed a subjective questionnaire, indicating the ease-of-use of the system, and the potential for use in a real setting.

Media Type.	RANDI	Paper Form
Pictures	3.5	1.5
Audio	0	1
Recommendations	2.5	3.5

Table 3: Average number of pictures, audio comments and recommendations captured using the RANDI and paper variations (recommendations were recorded in audio in the RANDI version, and hand-written in the paper version). The RANDI variation explicitly prompted users to capture three pictures and one audio recommendation.

Quantitative Results: The data that we gathered suggests that it takes about the same amount of time to complete the inspection using paper forms versus CAM (an average of 44 minutes using CAM versus 42 minutes using paper). However, the inspectors said that it ordinarily takes them 20-30 minutes to inspect parcels. The extra time was probably due to the distractions mentioned earlier. A longer, controlled study will be needed to understand the effects of RANDI on inspection completion time.

We also measured the average number of pictures, audio comments and recommendations that were recorded during each of the inspections (see Table 3). Recommendations were written in the paper experiment and audio recorded using RANDI. It should be noted that inspectors were explicitly prompted to capture three pictures in the RANDI version. While our data does not show much difference in the quantity of data that is captured between the two variations, in the future we plan to compare the impact of this multimedia data on follow-up actions taken by the internal control manager and the extension workers.

Qualitative Results: While none of the participants had used both versions of the system for a complete inspection, we gave them time to become familiar with both and then give their opinions. 3 out of 4 inspectors found the CAM version as easy or easier then the paper version (see Table 4).

All of the inspectors agreed that the main advantages of CAM were the ability to provide audio and image evidence

P.	CAM	Paper Form
1	1	5
2	2	1
3	2	2
4	1	2

Table 4: Participants' rating of ease-of-use of each variation on a 1-5 Likert scale (1 being easiest)

of the inspection, the lighter carrying load and the rugged nature of the plastic guide. Some participants commented that it was easier to talk to the producers, because they didn't need to worry about writing all the time. Another mentioned advantage was that using CAM it was not possible to alter the inspection information after it was entered. This reduced the possibility of foul play.

Some inspectors felt that it was hard to capture the barcodes in the shade. There was a consensus among users that if they had more practice, they would become much more comfortable. The basic mobile phone hardware and software design presented problems for some users. The menu was described as difficult to navigate, and they did not understand the purpose of all the buttons on the keypad. In general, there was some hesitation to use the mobile phone, due to its perceived cost and complexity. The same effect was not seen with the digital camera and voice recorder, possibly because they were both seen as single-purpose devices. Three out of four inspectors mentioned that motion video evidence would also have been useful, because it could provide evidence of how producers actually performed the work, which would also be a good source of content for training materials.

Even though we added multiple choice options during each of the design iterations, we still found more to be added during the last round of testing. There were also some questions that we were not able to convert to multiple choice. Additionally, using RANDI, some users wanted to but were not able to write down open ended inspection details. However, the internal control manager responded that this additional data was not necessary for monitoring, and that the inspection form could be even more concise.

The internal control manager found the blog tool to be very useful for browsing and searching inspection data. The generated reports were similar to the handwritten reports prepared by the inspectors earlier, with additional audio and image data. However, while the blog was useful, it did not provide the full functionality of a database application. For example, it was not possible to query on more then one type of field, or to produce the producer summary report currently hand-aggregated by the inspectors.

All the study participants were very excited about the tool and told us that they were looking forward to the full implementation. The internal control manager, who is in charge of the inspection process, wanted to use the system for the next internal inspection (starting two weeks after the usability tests).

4.4 Discussion

During the design and evaluation period, we were able to refine the RANDI documentation tool and get people excited to use it in the future. All of the staff and members of Asobagri that we interviewed were unanimously supportive of the system and our efforts.

Like we described earlier for the CAM DPS system, the RANDI mobile application is also flexible enough to connect to different back-end systems. For example, an agency involved in organic or bird-friendly certification could equip its field inspectors with a RANDI-like tool, and avail the same benefits that have been discussed.

Given the positive response of study participants, and the potential for impact in the agricultural sector, we are planning to continue our design studies, and eventually develop a full implementation of the system. We plan to have a working system ready for Asobagri by the next inspection cycle, starting in Spring 2007.

5. CONCLUSIONS

Small rural producers face significant challenges in managing their supply chain, monitoring production and accessing markets. CAM (as instantiated in the DPS and RANDI prototype applications) provides the first integrated mobile-phone platform for delivering these (and other) important services. We have also conducted the first usability investigation of these applications with actual users, considering a variety of delivery technologies (PCs, mobile phones and paper). Our preliminary results suggest that both applications are accessible to target users and will serve a real and viable need. Based on this positive response, we are planning further empirical evaluation and full implementation of both systems.

During our final discussion with Asobagri's executive director, he told us that these tools are directly addressing the most important issues that Asobagri is facing in its efforts to grow and reach new markets. These thoughts were echoed during a meeting with the managing director of Anacafe, the national coffee trade association of Guatemala. He told us that Anacafe would look forward to pilot testing and implementing our tools with other cooperatives in the future.

We are also planning to test the applicability of the same tools with other producer cooperatives (medicinal plants, agricultural) in rural India. Based on initial field visits, only small modifications to the CAM DPS and RANDI tools will be required for these contexts. In time, we hope to validate the utility of these systems, but it is not clear that can be done exhaustively through a simple controlled usability experiment. The real impact of these systems will be visible once they have been adopted and integrated into the operations of small producer cooperatives, and the results are apparent in their business.

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