A Mobile Solution for an Inclusive Public Distribution System in India

Shashank Garg[1] and Krishna Sundar[2]
[1]Handheld Solutions and Research Labs Pvt. Ltd. Bangalore India
[2]Indian Institute of Management Bangalore, India
garg.shashank@gmail.com
diatha@iimb.ernet.in

Abstract: The Public Distribution System (PDS) plays a significant role in the Indian government's poverty alleviation programmes and discharging its social development obligations by providing food grains and essential items to the rural and urban poor at subsidized rates. While the social objective is of protecting poor citizens from the vagaries of market forces, the PDS current system has several well documented problems such as lack of transparency, accountability, poor governance and poor service delivery mechanisms. Several suggestions have been made for improvement through technology intervention. In this paper we describe a mobile technology enabled system that we have developed. We have conducted a sample survey across urban slums to elicit responses about the existing PDS, to understand the problems faced by users and to obtain input on the features and functionality required to improve the PDS system. This questionnaire was designed and administered as a mobile form. The SmartPDS solution that has been developed uses low-cost mobile technologies and a workflows-based request tracking system to enable the delivery of critical governance services such as food entitlements, at the doorstep of the citizen. The system leverages the expanding cellular network to enable a consumer to place an order on a mobile phone and the entire process of PDS service delivery can be monitored and tracked in near real-time. An electronic voucher scheme has been developed to implement a cashless benefits transfer system to reduce leakages in the system and improve tracking of a PDS transaction from the generation of a consumer request to the delivery of food items to the consumer.

Keywords: SmartPDS, food security, electronic forms, electronic voucher, m-governance

1 Food security in the developing countries

The Food and Agriculture Organization (FAO, 2011) defines food security through the parameters of availability, access, utilization and stability. Availability is defined in terms of household food production and crop diversity. Access is defined in terms of the percentage of expenditure on food to the total household expenditure. Utilization is defined in terms of the degree of access to services such as water, health and sanitation. Stability is defined in terms of the stability of food prices and its supply (FAO, 2011). Despite substantial economic growth experienced in many developing countries and the progress in agricultural productivity which has resulted in increased per capita in food availability, food security remain a prominent global problem (Stringer, 2000). Sub-Saharan Africa and South Asia are the major geographic regions where the majority of the people who experience food insecurity live (Staatz, 2009; Africa, 2007). Different developing countries have tried to tackle food security through different mechanisms of state intervention but success has eluded them. State interventions have often been legitimized in the name of food security but protectionist measures have only succeeded in maintaining malfunctioning agricultural systems whereas new approaches should involve the public and private sectors in facilitating economic empowerment of the poor by introducing better technology interventions to improve agriculture production and distribution (Aerni, 2011). Bangladesh with large public distribution systems has tried to counter price increases due to middle-men cornering subsidized commodities, through strategies such as market-based price support to encourage farmers to store grain and for gradual release through the system (Khan and Jamal, 1997).

1.1 A review of the Public Distribution System in India

The Public Distribution System (PDS) in India is the oldest and most comprehensive anti-poverty programmes in terms of budgetary expenditures provided by the central and state governments (Food Corporation of India, 2003; 2005). The original objectives of the Indian PDS, defined in 1942, were to provide food-grains and other essential items to vulnerable sections of society at reasonable prices which are normally subsidized; to provide a moderating influence on the open-market prices of cereals; and to ensure equitable distribution of essential commodities so that vulnerable sections of society are not left to fend for themselves in the market. A modified system called Targeted Public Distribution System (TPDS) was introduced in 1997 to address certain systemic problems in the existing PDS. The primary focus of the TPDS shifted to delivering essential food items

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to the poor who fell below the poverty line in all areas of the country and to keep food subsidies within control following the failure of the earlier PDS (TPDS, 2005). In the new system consumers above the poverty line were to be provided essential food items at an economic cost whereas only those identified consumers who fell below the poverty line were supposed to benefit from budgetary food subsidies. The state governments had the responsibility of implementing the policies and processes involved in the public distribution system such as implementation of foolproof arrangements for identification of poor, delivery of food-grains to Fair Price Shops (FPSs) and the distribution of food-grains to the end beneficiaries in a transparent and accountable manner from the fair price shops under their supervision (Asthana, 2000). By 2008 the Public Distribution System in India comprised a nation-wide network of around 489,000 fair-price shops (Planning Commission, 2008a). The Government of India spent INR 176.12 billion in the year 2001-02 on food subsidy, which has grown to INR 750 billion for the year 2012-13 as shown in Figure 1 below (Planning Commission, 2012). The data shows that food subsidy has grown rapidly in the last five years.

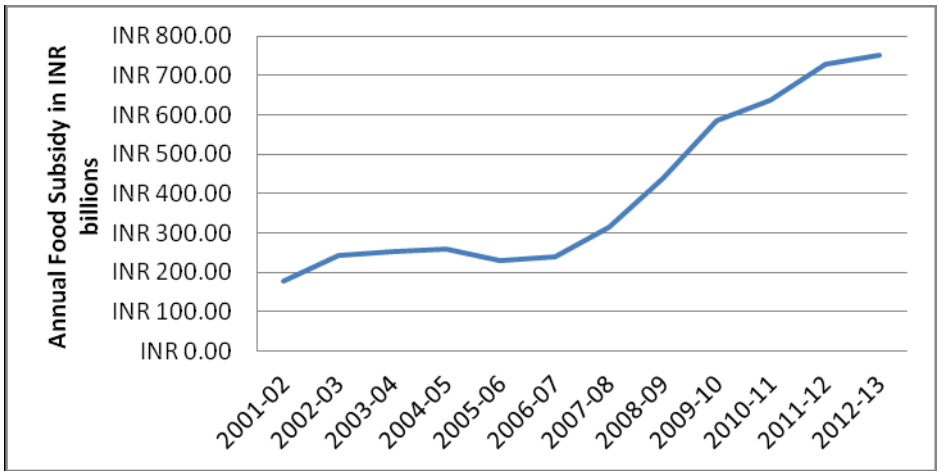

Figure 1: Annual Food Subsidy Bill (Source: Planning Commission, 2012)

Internal assessments of the PDS and TPDS have identified several problems such as inefficient procurement, storage, and delivery mechanisms. It has been found that the Government of India spent Indian Rupees (INR) 3.65 to transfer a benefit of INR 1 to the poor (where $ 1 = INR 55 approx.); 36% of wheat and 31% of rice were diverted from the system to the open market; implementation of the TPDS was plagued by large-scale errors of inclusion and exclusion amongst the targeted poor; the economic costs of grain were higher than the market price resulting in an inefficient system for the transfer of benefits to the poor; only about 23% of the fair price shops were economically viable; the delivery system needed to be made more efficient and transaction costs incurred in the delivery of services needed to be lowered through rationalized cost structures to improve the benefits for the intended beneficiaries (FCI, 2003; FCI 2005; Planning Commission, 2005). Other studies have also pointed out that inefficiencies, leakages and lack of governance in the TPDS have prevented it from meeting its primary objective of providing food grains at subsidized prices to the targeted rural and urban poor in the country (FCI, 2003; Ramaswami and Balakrishnan, 2002). Kerala, a state in southern India, which earlier had a well run and effective public distribution system, started exhibiting a steady decline in the effectiveness of the TPDS due to large-scale errors in targeting, corruption and systemic failures (Nair, 2011). Many aspects of public distribution have been studied to determine possible reasons for the lack of effectiveness of the system in India. While one study (Ahluwalia, 1993) claimed that there was no serious evidence of an urban bias in the public distribution system, this was subsequently disputed in another study which analyzed the same data using different measures and concluded there was strong evidence of an urban bias (Howes and Jha, 1994). Another study has indicated that the PDS has not adequately addressed food security since child nutrition has not improved (Tarozzi, 2005). Social development indicators such as primary education, literacy, development of human resources, consumption of fuel and power, availability of public transport, lack of access to timely and cost-effective government services, infant mortality, poor woman's and child health etc., also point to inequitable access to PDS and other services that affect the common citizen (Tarozzi, 2005; Planning Commission, 2008, 2008a, 2008b).

1.2 Motivation for a relook at the PDS in India

One of the important conclusions that can be drawn from a review of the existing PDS is that the PDS is unable to ensure delivery of food items to targeted beneficiaries in a process that is transparent and traceable. Large-scale errors of inclusion and exclusion, which are probably attributable to a lack of verifiable identity management in the PDS system, also need to be reduced. Errors in exclusion result in a large number of the rural and urban poor being unable to receive the benefits to which they are entitled and errors in inclusion result in those benefits being transferred or diverted to those persons who should not be in the targeted system. According to the eleventh five-year plan of the Government of India, the effectiveness and management of the PDS is to be improved with the help of IT and the introduction of a unique ID-based smart card system to address issues related to bogus ration cards and diversion of food-grains (Planning Commission, 2008).

In this paper we present an alternative solution that has been developed to address the two main problems that have been identified in the existing PDS; consumer access to PDS services in near real-time; errors in inclusion and exclusion. The proposed solution called "SmartPDS", uses mobile technologies to improve service delivery for improved last-mile access and electronic vouchers are used for enabling cashless transfer of benefits to the targeted citizens. It leverages the increasingly sophisticated cellular communications infrastructure to provide essential food security services at the doorstep of the citizen and helps shift the paradigm of e-governance to that of mobile or m-governance.

2 Requirements gathering through a field study

While the available secondary data highlighted problems in large-scale errors in exclusion and inclusion of beneficiaries in the system, this data did not provide guidance on the type of enhancements an improved PDS system should have. Therefore, a field study was designed and conducted to assess the satisfaction levels of PDS users with the existing system of fair-price shops, to gather functional requirements and to assess their likelihood and readiness to use a technology enabled solution. This study used purposive sampling strategies often used in public health research (Frankel and Devers, 2000; Devers et al., 2000) to enhance our understanding of the existing PDS. Segmentation of households was done by first asking the respondents if their households were users of the public distribution system through fair-price shops (FPS). Only those households that used fair-price shops for purchase of food items were included in the survey. The format of the questionnaire was kept close-ended to enable respondents to provide opinions on proposed features, rather than provide open-ended responses. The features and functionality incorporated in the SmartPDS solution have been based on the findings of this field study.

Determination of the sample size of a study, an important requirement since insufficient sample sizes can lead to several types of errors, was done using G*Power, a freely available calculator often used for statistical power calculations (Faul et al., 2007; Faul et al., 2009). Type I error causes an incorrect decision which results when a test rejects a true null hypothesis and the measure α defines the significance level of that test. Type II error represents an incorrect decision which results when a test does not detect a false null hypothesis. The rate of type II errors is represented by β and the statistical power of a test is defined as $(1-\beta)$ which is often used to compute the sample size of a study. For our study a value of $\alpha=0.05$ and $\beta=0.2$ were used as input parameters to G*Power which computed the required sample size as 64 households (see Figure 1 below).

2.1 Summary details of the Survey

A survey questionnaire (see Appendix A) with forty questions has been designed and administered through a face-to-face interview methodology to collect primary data for assessing the requirements for the SmartPDS solution. A Java-enabled Nokia 5830 cell-phone with an mForms application, based on open-source mobile forms technology enhanced by the authors, was used for rendering the questionnaire to collect responses from users in the sample households. A total of 73 households across urban slums in Bangalore, the capital of a state in southern India were covered. The average time to administer the cell-phone based questionnaire was 18 minutes. Figure 3 shows the annual household income reported by the households in Indian Rupees (INR) where $1 = INR 55 approximately.

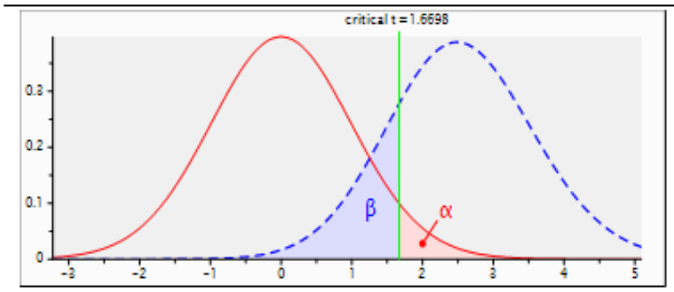

Figure 2: Sample size calculation

t tests – Correlation: Point biserial model
Analysis: A priori: Compute required sample size
Input:
Tail(s) = One
Effect size |ρ| = 0.3
α err prob = 0.05
Power (1–β err prob) = 0.80
Output:
Noncentrality parameter δ = 2.5158836
Critical t = 1.6698042
Df = 62
Total sample size = 64
Actual power = 0.8005036

Figure 2: Sample size calculation

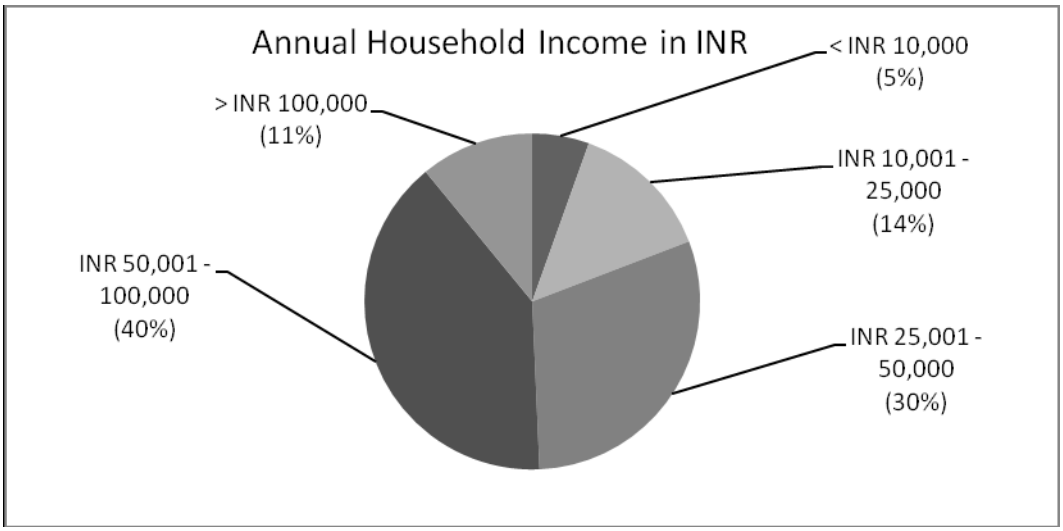

Figure 2: Annual household income of FPS consumers

In the income range below INR 100,000 per annum which covered 89% of the households, almost 63% of those households availed of PDS services through fair-price shops (FPS) for purchase of their main food items (see Table 1 below). Since 65% of the households also used neighbourhood shops for the purchase of food items, this indicates that the FPS was unable to satisfy all the requirements for main food items.

Table 1: Place of purchase of main food items

	Responses (as % as all users)			
Question	**Fair-price Shop**	**Neighbourhood Store**	**Department Store**	**Farmer's Market**
Where do you purchase the main food items for the HH?	63%	65%	10%	3%

Table 2 tabulates the usage and satisfaction level with the FPS and indicates that even though 92% of the households reported themselves as regular users of the FPS, over 63% of the users reported they were not satisfied with its service.

Table 2: Usage and satisfaction with FPS

	Responses (as % as all users)	
Question	**Yes**	**No**
Are you a regular user of the Fair-price shops?	92%	8%
Are you satisfied with the service at the FPS?	37%	63%

The respondents were also asked questions about the distance of fair-price shops from their houses, the number of visits required in a month, reasons for repeated visits and specific reasons for dissatisfaction with the FPS. Since 96% of the users reported that the FPS was located within a distance of 200 metres to 1 kilo-metre from their houses, it indicates that in urban areas the location of fair-price shops are within reach of a majority of the households. All users managed their transactions within a single visit to the FPS and spent an average of 31 minutes for that visit. Amongst all the users who expressed dissatisfaction with FPS service, the major reasons for dissatisfaction were listed as: 1) the poor quality of food items, and 2) non-transparent service at the FPS. The responses are tabulated in Table 3.

Table 3: Reasons for dissatisfaction with the FPS

Question	**Options**	**Responses (as % of all users)**
How far is the FPS from your house?	Less than 200 metres	1%
	Between 200 metres to 1 Km	96%
	Greater than 1 Km	3%
How many times a month do you visit the FPS?	Once a month	100%
	Twice a month	-
	More than twice a month	-
What is the reason for repeated visits?	To purchase in installments	-
	FPS is closed	-
	FPS does not have required items	-
	FPS does not have required quantity	-
Why are you not satisfied with the FPS?	Food quality is poor	70%
	FPS is not transparent	70%
	Behaviour of FPS owner is unpredictable	9%

Since the main objective of the study was to gather functional requirements for an improved solution, the rest of the questions were designed to elicit views of the users on potential improvement in service at the FPS through technology intervention. Summary of the relevant questions and responses are provided in Table 4.

Table 4: Technology assessment for improvement in FPS

	Responses (as % as all users)			
Question	**Yes**	**No**	**Not sure**	**Have not thought about it**
Do you think computerisation of the FPS would improve service?	51%	20.5%	8%	20.5%
Can you use the cell-phone easily?	50%	50%		
If you could order food items on a cell-phone, would you use the system?	48%	25%	4%	23%
If FPS could alert you by SMS to collect your order, would you use the system?	47%	25%	4%	24%
If given a choice of paying for goods safely and easily through the cell-phone, would you use the system?	45%	22%	5%	28%

The results indicate general readiness of users (48%) to adopt a mobile solution to interact with the FPS for placing orders, availing of short messaging services from the FPS outlet to keep abreast of the status of an order (47%) and paying for the goods through the cell-phone itself (45%).

2.2 The features and functionality of the SmartPDS

Based on the results of the sample survey, the following features and functionality are identified as part of the proposed a mobile technology enabled solution

- The consumer should be able to place an order for food items through a cell-phone
- The consumer should be able to receive SMS alerts for different phases of the transaction
- The consumer should be able to receive a response from the FPS outlet intimating availability and the specific quantity of goods as well as the estimated waiting time for the balance goods
- The consumer should be able to confirm the purchase to the FPS outlet for the quantity of food items currently available
- The consumer should be able to pay for food items through an electronic voucher automatically assigned to the transaction based on the quantity of entitlement benefits for that consumer
- The system should be able to track the entire transaction from the initiation of a service request by the consumer to the final delivery of food items by the FPS outlet to the consumer
- The system should be able to ensure that only properly authenticated consumers are able to initiate requests in the system (identity management for enforcing exclusion and inclusion criteria)

Details of the mobile technology enabled SmartPDS solution that has been developed based on the above functional requirements is described in the following sections.

3 The proposed mobile solution for the SmartPDS system

The core components of SmartPDS are the software applications that address the needs of the consumer, the FPS retail outlet and the back-end server. All the stake-holders are able to access the public distribution system on a range of mobile devices such as low-cost Java-enabled cell-phones, smart-phones, tablets or even through the web. Figure 4 presents a diagrammatic representation of the top-level interactions that occur between the various entities within SmartPDS.

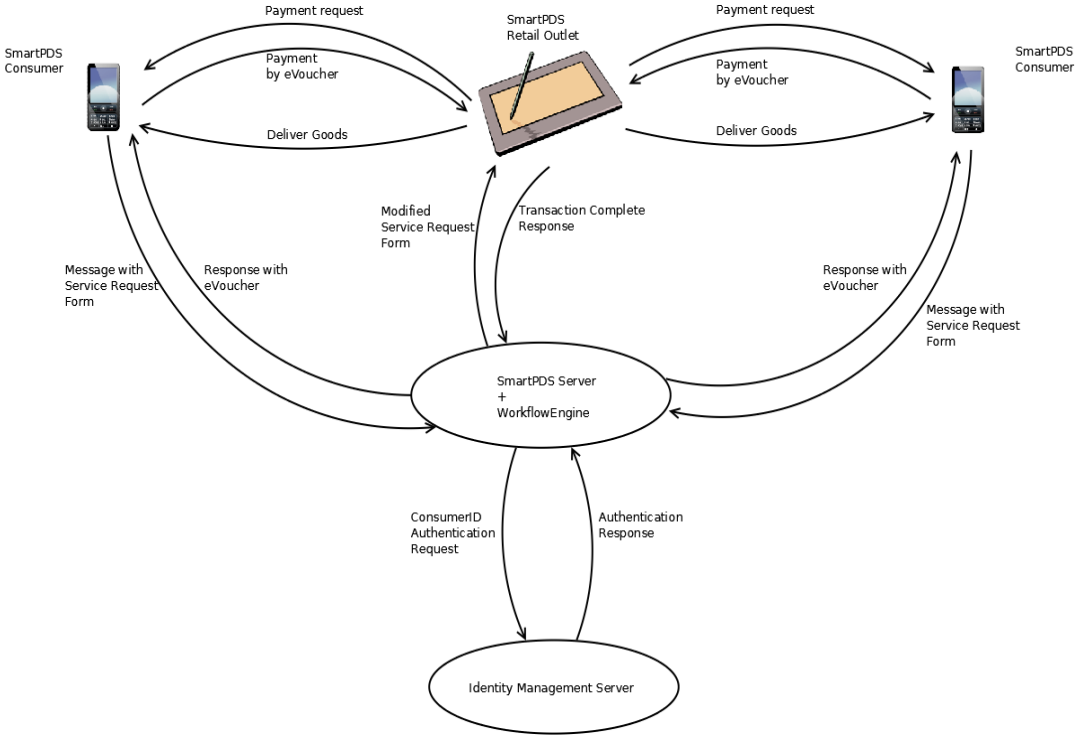

Figure 1: Top-level interactions between the entities in the SmartPDS System

3.1 Key technologies used in the SmartPDS System

The SmartPDS system uses several key technologies to enable the mobile phone to function as an access device. These technologies (cellular infrastructure, electronic forms, identity management and electronic vouchers) are summarized in the following sub-sections.

3.1.1 The cellular infrastructure

Cellular telephony allows the same digital communications infrastructure to support of voice and data applications simultaneously. Hence, the cellular communications infrastructure is used in the SmartPDS to enable the real-time exchange of data between mobile devices in the field and the application server. Important functions such as form-filling for request generation, identity verification and tracking of the service request over its entire life-cycle can now be done in near real-time. The growth of cellular infrastructure in India during the period from 2007 to 2010 shown in Table 5 below indicates that the rate of growth of cellular telephony coupled with the increased coverage in rural areas is of significant value since last mile connectivity infrastructure can now leveraged for developing a mobile solution to the PDS.

Table 1: Growth of Telephony in India (Sources: TRAI, 2007; 2008; 2009; 2010a; 2011)

	Financial Yr from April 1 to March 31			
	2007-08	**2008-09**	**2009-10**	**2010-11**
Wire-line Subscribers (in millions)	39.42	37.96	36.96	34.73
Wireless Subscribers (in millions)	261.07	391.76	584.32	811.59
Broadband Subscribers (in millions)		6.22	8.77	11.89
Subscribers added per month (in millions)	8	10	15	18.9
Rural Tele-density	9.2%	15.2%	24.29%	33.79%
Overall Tele-density	26.22%	36.98%	52.74%	70.89%

3.1.2 Electronic forms

Electronic forms are used for the primary interface between the consumer and the PDS. Forms are based on XForms technology, an open standard for the design and implementation of electronic forms (Boyer, 2009). A forms interpreter is required for rendering electronic forms on any mobile device. In the SmartPDS we have used software from the OpenXdata platform, an open-source software that provides a complete XForms compliant environment for design and deployment of forms-based mobile applications (OpenXdata, 2011). This software has been enhanced by the authors to provide additional functionality such as workflows that are required by the SmartPDS server. The authors have also developed an entirely indigenous client application (called mCollect) for Android-based smart-phones. So a consumer in the SmartPDS system may either use a low-cost Java-enabled cell-phones or an Android smart-phone to access services within the public distribution system. A service provider at the fair-price shop or retail outlet may also use a low-cost cell-phone or an Android smart-phone to service requests from consumers registered with the PDS.

3.1.3 Consumer identity management for the retail consumer

Since large-scale errors in inclusion and exclusion have been identified as a major problem in the existing PDS, the proposed SmartPDS uses consumer identity management extensively for better targeting of the consumers. Considerable amount of research material is available on identity management in the context of social services. Digital identity management has been used extensively in Italy for public administration, e-government services and in private sector applications (Grandi, Mandreoli et al., 2004; Hoffmann & Stotz, 2005; Corradini, Paganelli et al., 2006; Corradini, Paganelli et al., 2007; Leenes, Schallabock et al., 2007). Various identity management techniques have already been applied successfully in the context of health-care services (Coyle, 1999; Leenes, Schallabock et al., 2007; McClanahan, 2008; Plomp, 2011). Similarly, the management of digital identities is of critical importance to the success of any social and food security system when transitioning from a paper-based identification system to an electronic system.

The objective of identity management in the proposed system is to properly identify the target beneficiaries to provide them the services and entitlements in a transparent manner and prevent the use of fake identities to deter non-beneficiaries from manipulating the system. Duplication of identities and masquerading often occur at this stage, leaving the real poor uninformed of their rights and robbed of essential goods and services (FCI,

2003). Traditionally, local governments in the various states of India have used paper-based ration cards to help in this identification process. Ration cards are assigned on a per-household basis and define the range of food entitlements based on economic and social criteria. Unfortunately, the benefits of the PDS / TPDS have failed to reach the intended beneficiaries due to duplication of the paper-based ration cards, inadequate authentication of identity and other systemic problems (TPDS, 2005). Some states are also experimenting with smart-cards to replace the existing paper-based ration cards. Identity management in the proposed SmartPDS system is based on low-cost 2D-barcoded and laminated cards that carry basic identity information of the consumer and authentication of credentials is done over the communications channel which is already available. As the cost of cellular services and products comes down, the cell-phone may itself be used in identity management since it could hold a bar-coded image and other credential information within the mobile device. A future version of the SmartPDS will interface with the "Aadhar" scheme for identity management specified in India's Unique Identification project (UID) when it becomes widely available (UIDAI, 2009). According to current figures, over 130 million people have already been enrolled in the scheme till February 2012 (UIDAI, 2012). The functionality in SmartPDS system is capable of being extended through external web services implemented using *Representational State Transition* (REST) architecture (Fielding, 2000). The UID scheme for authentication of citizen identities will be incorporated within SmartPDS by implementing the appropriate plug-in module when UID becomes widely available.

3.1.4 An electronic voucher for cashless transfer of entitlement benefits

The concept of an electronic voucher (eVoucher) system for the transfer of benefits to consumers without a cash transaction has also been developed in this paper. The existing public distribution system has experienced difficulty in implementing a transparent system of cash based entitlements that can be delivered effectively to the targeted poor (Planning Commission, 2005). Anecdotal evidence from several initiatives suggests that either cash entitlements do not reach the end beneficiary or they are often abused by the men in the family, resulting in unmet social objectives. Some of the problems that have been identified in traditional paper-based food stamps or food coupons in many countries are high administrative costs, abuse of food stamps and diversion of benefits through an underground economy in which food stamps are transacted for other goods and services (Harris, 1997). A pilot project for electronic benefits transfers through banking channels was implemented in Maryland (USA) and an empirical study designed to obtain feedback on this project indicated that the various stake-holders were largely satisfied with electronic benefits transfers compared to the paper-based system of food stamps (Harris, 1997). Due to increasing popularity of electronic commerce through the internet and the mobile phone, several payment mechanisms such as e-cash, credit cards, electronic vouchers and electronic wallets have been developed for facilitating electronic transactions. Secure offline payment systems incorporating digital vouchers have been implemented on cell-phones with near-field communication (NFC) to achieve phone-to-phone transfer of digital vouchers (Van Damme et al., 2009; Francis et al., 2010; Li et al., 2010). Fan and Huang (2010) have proposed a secure e-cash scheme for offline and online payment which incorporates provable security.

Since the SmartPDS system is targeted towards the poor with relatively negligible access to modern banking services like mobile banking, an electronic voucher scheme has been developed to replicate the functionality of food coupons or other forms of entitlements in SmartPDS. The eVoucher scheme implements cash-less transactions in the targeted public distribution system under the control of a workflow engine. It uses electronic forms and mobile devices for a seamless payment mechanism that is essential to the success of SmartPDS itself.

An eVoucher is an electronic record incorporating a unique identification number, a consumer ID, and a field that defines the value of the eVoucher in monetary terms. Since the eVoucher contains a consumer ID, it can only be assigned to a specific consumer or family, unlike food-stamps which are freely transferrable and often ineffective in controlling the exclusion of people from the targeted group. The value embedded in the eVoucher represents the notional cash value of this entitlement. In an electronic form the voucher can be transferred between various systems and then destroyed when its value drops to zero. Hence an eVoucher has a finite life that starts when a cash entitlement or allocation is issued to a consumer and ends when the stored value is exhausted after multiple purchases have been made by the consumer in the PDS chain. A new number is then generated in the next cycle of disbursement of entitlements.

The basic premise behind the eVoucher is that certain cash entitlements are supposed to be provided to the targeted poor in rural and urban areas at some periodic intervals based on social and food security policies laid down by the government from time to time. Within the confines of the Public Distribution System which provides essential items of food security to the targeted poor, it is feasible to define a new approach that replaces the periodical disbursal of cash entitlements from physical cash transactions to their electronic equivalents which can only be used at the retail outlets within the PDS network. Of course, this may appear to place limits on the social acceptance of eVouchers due to their applicability within the public distribution system but that is not the case. Any retail service provider willing to offer other goods and services on the basis of eVouchers could potentially join the PDS system and use the SmartPDS Server to mediate the interchange process.

The eVoucher is conceptually analogous to the food-coupon system that is prevalent in the IT industry where a certain component of monthly perquisites to employees is distributed through food coupons which can then be used to purchase food items at any retail outlet that accepts those coupons. The targeted poor should also have similar benefits of food coupons through a secure and trackable electronic voucher system that uses mobile communications and computing technologies.

3.2 The software components of the SmartPDS system

The SmartPDS system comprises the following software components: the SmartPDS Consumer; the SmartPDS Server; and the SmartPDS Retail Outlet or service provider. Each of these modules is described here. A simplified notation from the Business Processing Modeling Notation (BPMN) specification has been used to describe the functional tasks and interactions as parallel processes within the SmartPDS system comprising a server, a retail outlet and the consumer (OMG, 2009). The business process diagram shown in Figure 5 provides a simplified overview of all the business processes involved when a PDS consumer issues a request for purchasing food through her cell-phone application.

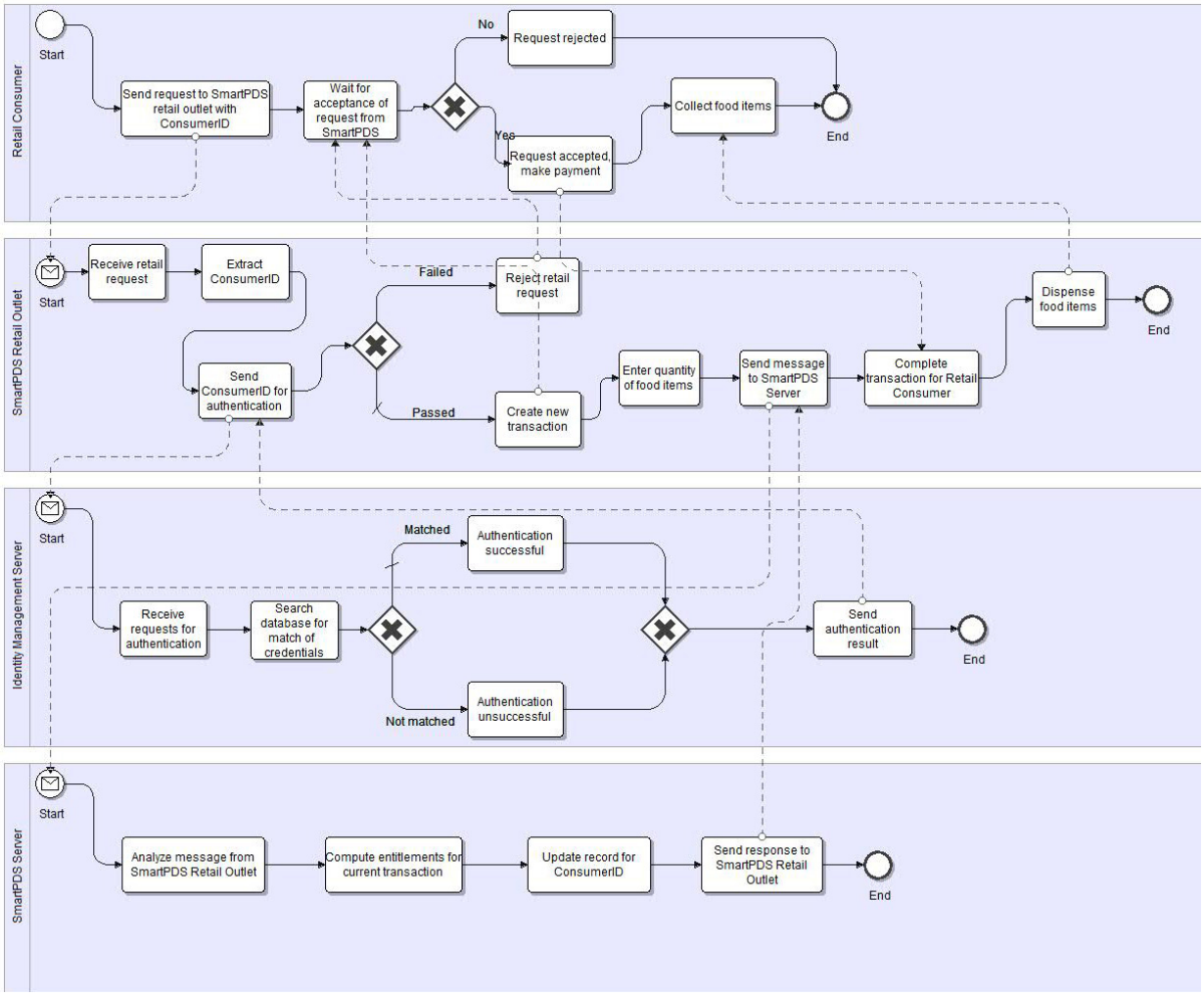

Figure 2: The SmartPDS system

There are four major entities involved in the transaction: the retail consumer, the SmartPDS retail outlet, a centralized identity management service and the SmartPDS backend service. When a retail consumer makes a request, the consumer's digital identity is sent by the retail outlet to the centralized identity management service to authenticate the consumer in real time. On successful authentication of the consumer's identity, a request is sent to the SmartPDS backend server for the food entitlements that are to be provided to the targeted consumer. On receiving the list of food entitlements, the retail outlet collects payment and dispenses the requested food items. Since the back-end server maintains a record of all transactions, it provides a check on the retail service provider and helps improve transparency in the distribution system.

3.2.1 The SmartPDS Consumer

All citizens registered with the targeted public distribution system have a consumer identification number. On a successful login, the consumer is presented a service request form to be filled up to order food items from the FPS (see Figures 6 & 7 below).

Figure 3: Service request form on low-cost cell-phone

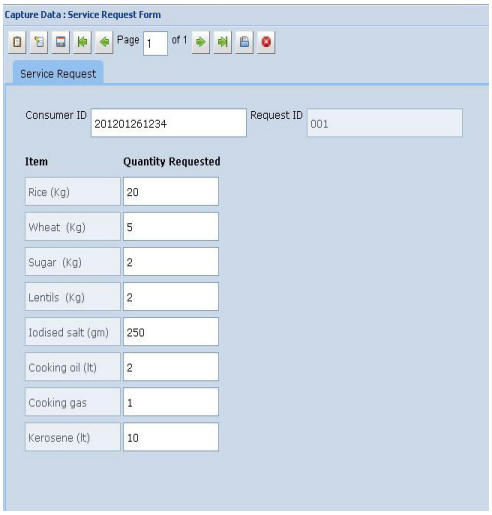

Figure 4: Service request form on a smart-phone

The consumer service request form is uploaded to the server where the consumer's identity is authenticated and a response is sent back to the consumer in a modified request form, a pre-filled form that lists the quantities of food items allocated to the consumer based on the entitlement policy, along with an eVoucher number. The server also sends the modified request form to the retail service provider who issues a payment request to the consumer based on goods that are deliverable. The consumer waits for a payment request from the retail service provider, and approves the purchase by selecting those items he wishes to purchase at the indicated price. This approval process is implemented through a purchase order form in which the consumer uses the eVoucher number assigned by the server. Based on the value of the purchase, the appropriate number of eVoucher units are debited from the consumer's account and credited to the retail service provider's account. Thus a complete transaction can take place without any cash transfers in the process, tracked by the SmartPDS Server at each stage of the process.

3.2.2 The SmartPDS server

The architecture diagram for the SmartPDS Server is given in Figure 8 below:

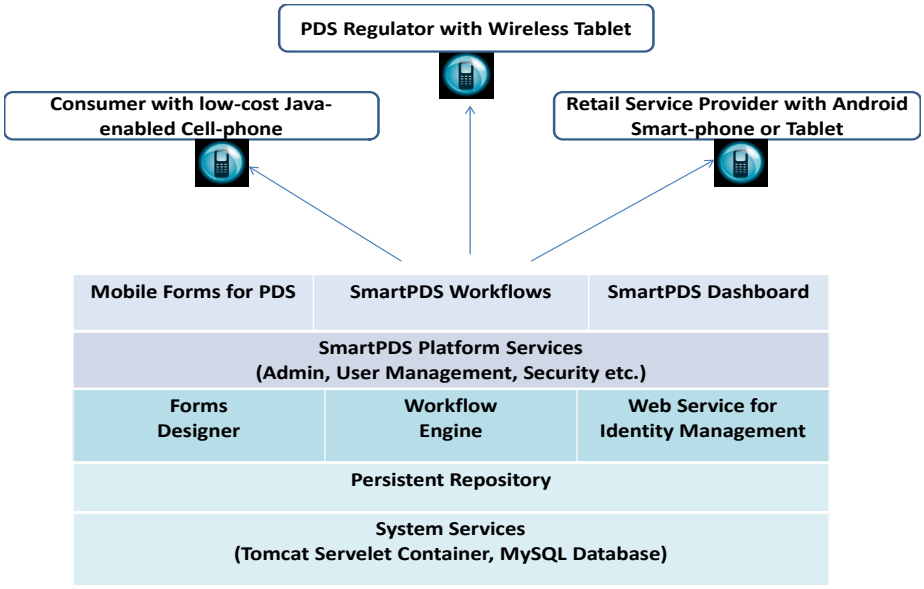

Figure 5: Software architecture of the SmartPDS Server

The SmartPDS Server provides all the back-end services and workflow processes required to implement the services and interactions between a consumer and the retail service provider. It comprises the forms based services encapsulated in a layered architecture of software modules that incorporate a forms designer, a workflow engine and workflow servelets, the business processes, a set of platform services for the administration of the server, and a persistent storage repository for forms and data. All interactions are managed by a workflow engine that uses electronic forms to exchange data between different processes. The server waits for messages from the consumer, in the form of consumer service requests, or status messages from the retail service provider. XML documents are used to exchange data between processes in the system workflows. Since the server is always waiting for messages from the consumer or the retail service provider, it analyzes these messages and takes appropriate action. On receipt of a new service request message it is queued up. When the consumer fills up a Service Request Form and uploads it to the server, the workflow engine initiates a work-item for the Server. The server extracts *ConsumerID* information from the service request form and sends a request to an identity management service for verifying the identity of the consumer. The server accesses the consumer's record repository to extract information about the entitlements to be allocated to this consumer, assigns an electronic voucher with an appropriate value and queues it as a work-item for the retail outlet. A response is also sent to the consumer who will use the eVoucher assigned to it to complete the transaction with the retail service provider.

The server adds a "Quantity Allocated" column in addition to the existing "Quantity Requested" column which is grayed out and is no longer available for editing. The allocation is based on the specific consumer's entitlements which may change from time to time. An eVoucher number is assigned along with the value of the eVoucher units. The server also indicates that the request has been approved. This form is sent to the consumer as well as to the retail outlet for completion of the transaction. The server always retains monitoring and control over all transactions to ensure that the retail service provider has actually provided the appropriate quantity of goods that the consumer is entitled to receive. A modified service request form generated by the server is shown in Figure 9 below.

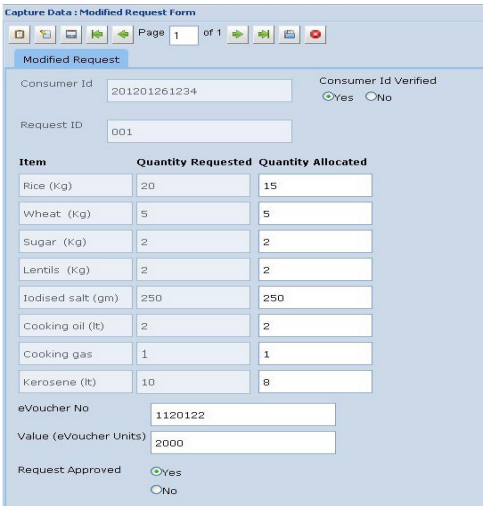

Figure 6: The modified service request form generated by the server

On receipt of a "Transaction Complete" message from the retail service provider to the server, the consumer's transaction record is updated and the service request is removed from the queue by the server. The server may also receive a "Stock Item Request" message from the retail service provider in case of a shortfall in stocks of food items with the retailer (Figure 10).

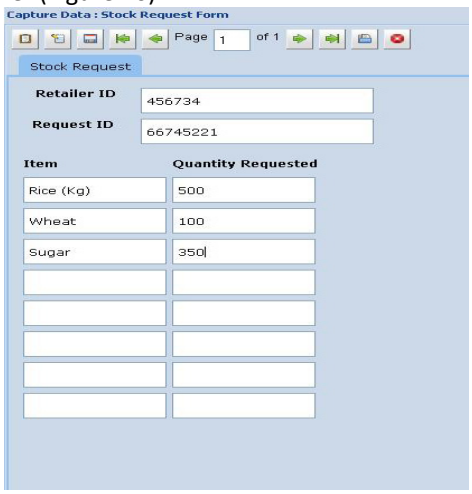

Figure 7: The stock request form generated by the retail outlet

Arrival of a stock-item request at the server initiates the process of shipping food items from a district level warehouse to the requesting retail outlet. If the district warehouse does not have adequate stock the request is accelerated up the supply chain and good are acquired from other warehouses in the distribution chain.

3.2.3 The SmartPDS Retail Outlet

The third major entity within the SmartPDS system is the retail outlet or service provider which represents the fair-price shop in the existing public distribution system. Since the targeted consumers interface with the food security system through the retail outlets, it is important to monitor the working of the retail outlets to improve accountability and transparency in the system. The retail outlet receives its work orders from the server and not directly from the consumer. This mechanism helps to ensure that the complete transaction is executed under supervision of the server. On receipt of a modified service request form containing details of the quantities of food items allocated and an eVoucher with a certain value, the retail service provider workflow checks if the requested food items are available in the quantities required. If the goods are available, the retailer sends a payment request (see Figure 11) to the consumer who then makes the payment through eVoucher value assigned to him by the server. If the retailer has a shortfall of food items, a stock request is generated to the SmartPDS server which informs the warehouse to issue the ordered items.

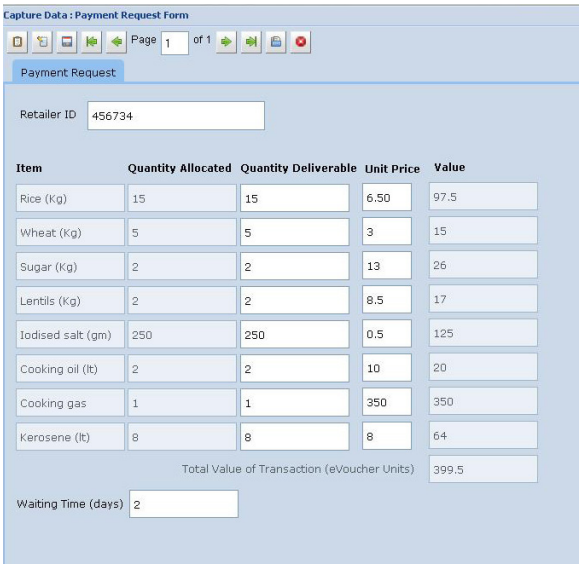

Figure 8: The payment request form generated by the retail outlet

The retail outlet workflow retains the "Quantity Allocated" column and adds the "Quantity Deliverable" column, a "Unit Price" column and a "Value" column. It also specifies a waiting time because the goods may not be immediately available. The value field is computed automatically within the form itself as the retail service provider fills up the "Quantity Deliverable" and "Unit Price" fields for each item. The total eVoucher units are also computed automatically, thereby minimizing the potential for human errors. Cells that are grayed out are no longer available for editing by the retail service provider. This form is sent to the consumer for payment and confirmation of the purchase order. The purchase order form (see Figures 12, 13) is generated by the consumer on a low-cost cell-phone, in response to the payment request form, and sent back to the retail service provider to accept the quantity of items specified in the payment request form. Against each item, the consumer can specify whether that item is required or not.

Figure 9: The purchase form on low-cost cell-phone

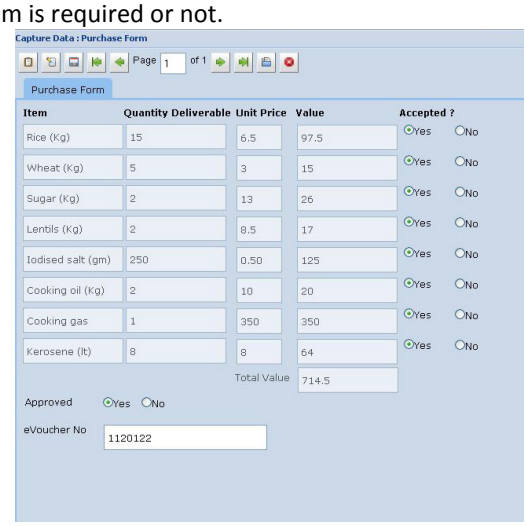

Figure 10: The purchase form on smart-phone

The total value of the transaction is recomputed after consumer fills in the purchase order form. In addition to indicating approval, the consumer also enters his eVoucher number. This is verified with the eVoucher number sent to the retail outlet by the server in the modified request form and the value in the eVoucher is accepted only if the eVoucher numbers match. The retailer send a "transaction complete" message, the eVoucher is credited to the retailer's account and debited from the consumer's account by the server and food items are handed over to the consumer.

4 Conclusions

This paper presents a mobile technology enabled solution for improving service delivery in the Public Distribution System in India. A field survey was conducted and based on the sample survey a set of features have been defined and incorporated in a mobile-phone based solution to address the identified problems. Improvement in service delivery is achieved through the use of electronic forms on low-cost cell-phones under the supervision of a workflow system to manage requests from mobile users and generate SMS alerts when the goods are ready. Improvement in transparency is achieved through the tracking mechanism of a service request from its initiation by the consumer to its fulfillment by the retail outlet. Similarly, the transfer of entitlement benefits to the intended consumers is achieved through the use of electronic vouchers managed by a workflow-based tracking system. Transfer of benefits through an eVoucher system ensures cashless delivery which improves compliance for the targeted consumers. This helps in empowering poor consumers to access these food entitlement services at their doorstep.

Since the SmartPDS system uses mobile connectivity to properly authenticate users in a central database for transactions between the retail outlet and the end consumer, exclusion and inclusion errors can be controlled in near real-time. The mobile phone based SmartPDS system is scalable and replicable since it uses low-cost cell-phones and the existing cellular infrastructure. Hence the cost of technology intervention is relatively low and it can be replicated in other developing countries.

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Appendix A: The Survey Questionnaire

Name of Respondent: _____
House Address: _____
_____
City: _____
PIN Code:
Phone No: ☐☐☐☐☐☐-_____

Interviewer Code: ☐☐
Date of interview: ☐☐☐☐ ☐☐ ☐☐

1. Please tell us about your household

1.1 How many persons are usually resident in your HH?
(for 6 months or more)
1.2 How many years have you lived in this HH?
1.3 How many earning members are in your household?

1.4	In which category is your annual household income, approximately?	1	Less than Rs. 10,000
		2	Rs. 10,001 to Rs. 25,000
		3	Rs. 25,001 to Rs. 50,000
		4	Rs. 50,001 to Rs. 100,000
		5	Above Rs. 100,000
1.5	Does your household have a ration-card?	Yes=1, No=2	
1.51	If yes, is it BPL or APL?	BPL=1, APL=2	
1.52	If not, why not?	1	Did not apply
		2	Applied, but not yet received
		3	Other (*please specify*)

2. Please tell us about utilities in your household (Electricity, water, cooking)

2.1	Does your HH have electricity?	Yes=1, No=2	
2.2	What is the main source of drinking water?	1	Water piped to your house
		2	Water piped to
		3	Public tap
		4	Tube-well or bore-well
		5	Bottled water
		6	Tanker water
		7	Other (*please specify*)
2.3	What is the primary fuel used for cooking?	1	Kerosene
		2	Charcoal
		3	Agricultural crop
		4	Waste material or shrubs
		5	Animal dung
		6	Gas
		7	Wood
		8	Electricity
		9	Other (*please specify*)
2.4	Where do you purchase the main food items for the HH? *(please click all that apply)*	1	Fair-price shop
		2	Neighbourhood shop
		3	Department store
		4	Farmer's market
		5	Other (*please specify*)

3. Please answer a few questions about your house

3.1	Is it your own house or rented?	1	Owned house
		2	Rented house
3.11	If own house what would be the monthly rental value at which you would rent it to someone else		
3.12	If rented house, how much monthly rent do you pay?		
3.2	What is the structure of your house?	1	Permanent structure
		2	Semi-permanent structure
		3	Brick
		4	Concrete blocks
		5	Bamboo
		6	Mud
		7	Temporary shelter
		8	Other (please specify)

4. Ownership of household articles

4.1	Which of the following household articles do you own? *(click all that apply)*	1	Cell-phone
		2	Landline phone
		3	TV
		4	Radio or Music system
		5	Fridge
		6	Electric fan

		7	Pressure cooker
		8	Gas cylinder
		9	Sewing machine
		10	Washing machine
		11	Furniture
		12	Bicycle
		13	Two-wheeler
		14	Four-wheeler

5. Please tell us about your average household expenditure

	Item of expenditure	Monthly expenditure
5.1	Food	
5.2	Education	
5.3	Electricity & Water	
5.4	Cell-phone	
5.5	Work-related Travel	
5.6	Others	

6. Please tell us about the food habits of your household

6.1	What are the major food items consumed in your household? (*Click all that apply)*	1	Rice
		2	Wheat
		3	Raagi
		4	Lentils
		5	Sugar
		6	Salt
		7	Spices
		8	Vegetables
		9	Fruit
		10	Meat
		11	Poultry
		12	Fish
		13	Others (*please specify*)
6.2	Which of these cooking oils does your family consume regularly? (*click all that apply*)	1	Groundnut oil
		2	Coconut oil
		3	Mustard oil
		4	Linseed oil
		5	Sunflower oil
		6	Palm oil
		7	Ghee
		8	Butter
		9	Other (*please specify*)

7. Please tell us about your experience with the Public Distribution System

7.1	Are you a regular user of the Fair-price shops?	Yes=1, No=2	
7.11	If not, why not?		
7.2	How far is the FPS from your house?	1	Less than 200 metres from house
		2	Between 200 metres to 1 Km
		3	More than 1 Km
7.3	How many times in a month do you visit the FPS?	1	Once a month
		2	Twice a month
		3	More than 2 times
7.4	What is the reason for repeated visits? (*select all that apply)*	1	To purchase in installments
		2	FPS is closed
		3	FPS does not have required items
		4	FPS does not have required quantity

		5 Too much crowd
		6 Other (please specify)
7.5	How much time do you spend on each visit?	
7.6	Does your visit to FPS result in loss of wages?	Yes=1, No=2
7.7	Are you satisfied with the service at the FPS?	Yes=1, No=2
7.71	If not, why not? (*please select all that apply*)	1 Food quality is poor 2 Food prices too high 3 FPS service is not transparent 4 Behaviour of FPS owner is unpredictable 5 Other (*please specify*)
7.72	Any suggestions for improvement?	

8. Some questions on an improved delivery system

8.1	Do you think computerisation of FPS would improve service?	1 Yes 2 No 3 Not sure 4 Have not thought about it
8.2	Can you use the cell-phone easily?	Yes=1, No=2
8.21	If not, can you learn from someone?	Yes=1, No=2
8.22	If you could order food items on a cell-phone, would you use the system?	1 Yes 2 No 3 Not sure 4 Have not thought about it
8.23	If FPS could alert you by SMS to collect your order, would you use the system?	1 Yes 2 No 3 Not sure 4 Have not thought about it
8.24	If given a choice of paying for goods safely and easily through the cell-phone, would you use the system?	1 Yes 2 No 3 Not sure 4 Have not thought about it
8.25	What else would you like to see for improving the system?	