

A LITERATURE REVIEW ON AUTOMATIC DISTRIBUTION SYSTEM

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Abstract—The Public Distribution System serves as a vital infrastructure for supplying basic goods at discount prices to impoverished populations, especially in developing countries such as India. However, traditional PDS procedures have long suffered from inefficiencies, fraud, corruption, and mismanagement because of human interference and antiquated technology. Various automated systems that capitalize on technologies like embedded systems, IoT, and biometric authentication-including facial recognition-have recently been proposed and implemented to solve these problems in the last decade. The present paper performs a comprehensive literature review, focusing on the incorporation of facial recognition technology in the automated ration distribution system. Consequently, the current modernization approaches of PDS in the utilization of IoT, GSM, RFID, and biometric systems will be outlined in the survey. The benefits of the systems include increased transparency, minimal human intervention, real-time monitoring, and secure authentication methods. The distribution of rations is also discussed in the study in terms of some strategies, including the accurate dispensing of items through the use of microcontrollers, load cells, and solenoid valves. **Research Findings:** The finding of the evaluated study reveals that the more accurate distribution, fraud considerably reduced, with the help of automated solutions. Many reasons why these systems are hard to implement include high initial costs, technological complexity, data security problems and scalability. It also points out gaps in the researched areas and existing literatures such as the need for solutions that are commonly used and more affordable ones that may be constructed with even stronger data security and scalability. Finally, possible applications of these automated rationing systems are highlighted, and several recommendations are put forth to extend mobile-based solutions in place of those designed for remote areas where making use of a blockchain for transaction records will be safe. The latest AI machine algorithms for better performance in face recognition are also recommended. Hence, the literature review concludes that while highly impressive in automating PDS, in particular, much more work has to be done for full realization at scale, notably in resource-constrained settings.

Index Terms—Automated Ration Distribution, Public Distribution Systems (PDS), Internet of Things (IoT), Face Recognition Technology, Biometric Authentication, Open-Source Solutions

I. INTRODUCTION

Public distribution systems, or PDS, are introduced in many countries, especially developing ones like India, to ensure food security and distribute basic commodities like rice, wheat, sugar, and kerosene to the poorer section of society at reduced prices. The system [1] ensures that essentials reach even the most susceptible populations, which is one of the fundamentals of welfare schemes to alleviate hunger and poverty. Although this traditional PDS structure has been in existence for decades with deep-rooted corruption and inefficiencies, it is a very crucial one. The manual handling of ration distribution resulted in many handling loopholes, thereby thefts of rations, inadequate production, and bad management. Major drawbacks with the traditional PDS are manual handling of ration card verification, goods distribution, and record-keeping. These problems leave the system vulnerable to fraud and human error. Ration dealers and shopkeepers often take advantage of beneficiaries by tampering with ration cards and records, underweighting items, or transferring stock to the black market. In addition, flaws in the distribution process make rations unavailable to intended recipients, especially in remote and rural areas. General lack of accountability and transparency has exacerbated these issues, creating a lack of efficacy in PDS. Since the invention of technology, there has been a great push toward automation of PDS. All of these [2] technologies have been studied with the intention of modernizing and automating the distribution process. These include Internet of Things (IoT), embedded systems, RFID, biometric systems- facial recognition, fingerprint, and also cloud-based data management. Fraud would be at minimum since such technologies would mean the complete elimination of manual involvement in ration distribution, thus it would be secure, efficient, and very transparent. The PDS automation comes with the usage of high-end technologies in recording transactional data, product dispensing, and even beneficiary authentication. For instance, IoT-based solutions

can provide the authorities with real-time stock level and monitoring of transaction that occurs at each stage of rations' distribution. As for this, an automated dispensing system of rations will ensure reaching the intended beneficiaries precisely and without penetration while RFID and biometric technologies ensure rations to be available only to approved beneficiaries. It is very interesting to use facial recognition technology [3] since this can safely and discreetly confirm who the beneficiary is. Face recognition systems capture photos of the user's face using cameras and then compare those images with earlier recorded information in a database. With this technique [4], it is no longer a requirement to use actual cards, tokens, or fingerprints which can be lost, stolen, or duplicated. The other advantage of face recognition [5] is that it allows for a smoother experience for the user; therefore, it is commercially viable to automate PDS, especially in rural areas where users might not be able to keep track of physical tokens or retrieve traditional ration cards. Several research works have been performed to explore the development and deployment of automated systems for ration distribution with particular focuses on several technologies and strategies that could be directed toward addressing specific issues. This review literature will, therefore, aim to present a comprehensive analysis of the different approaches with special emphasis on technological advancements in the automation of PDS [6], raising associated obstacles and unmet needs for research. As we discuss PDS automation through Internet of Things, embedded systems, biometric systems, and facial recognition technologies in the context, we evaluate their overall impact on increasing transparency, reducing corruption, and ultimately optimizing the distribution process as a whole. We also discuss the benefits and the challenges in the implementation of such systems, as well as real-life illustrations of their performance. Additional directions of further research are also covered, including enhancing security for information, ensuring cost-effectiveness of such systems in massive deployments, and enhancing scalability. This review tries to contribute towards the conversation already going on regarding the modernization of public welfare programs and how new technologies may assist disadvantaged communities in achieving food security.

II. RELATED WORK

Traditional Public Distribution Systems [1], Due to their heavy reliance on human processing, traditional systems were vulnerable to manipulation. There is enough evidence of issues like ration theft, illegal sales, and inappropriate measures. The concepts like GSM and RFID were invented earlier to trace and authenticate ration card holders to automate a part of the ration distribution process.

IoT-Based Ration Distribution Systems conferred automated dispensing, real-time monitoring, and centralized data management. Typically, these systems [3] involve a combination of GSM and RFID technologies to track client transactions while ensuring on-time delivery. Extensive research has proven the suitability of microcontrollers, solenoid valves, and load cells

to facilitate proper and accurate goods dispensation without human intervention.

One of the fast-emerging areas of PDS automation is [4] face recognition. It has been proposed that systems that use cameras and recognition algorithms, like Haar Cascade, can verify the identity of the users and could do away with the need for ration cards or fingerprinting. Main advantages of these systems include security and non-intrusiveness. Real-time monitoring and updates through IoT further enhance the transparency of these systems.

TABLE I
COMPARISON OF TRADITIONAL PDS, IOT-BASED SYSTEMS, FACE RECOGNITION SYSTEMS, AND HYBRID SOLUTIONS

Category	Traditional PDS (Various Authors)	IoT-Based Systems (Madur et al., 2013)	Face Recognition Systems (Bhele & Mankar, 2012)	Hybrid Solutions (Valarmathy & Ramani, 2013)
Authentication	Manual (Ration cards)	RFID, Biometric (Fingerprint)	Face Recognition (AI-based)	Face Recognition + IoT
Cost	Low initial, high fraud cost	High setup cost	High cost (hardware, AI)	High cost, scalable
Accuracy	Prone to error	High (automated dispensing)	High, but sensitive to lighting	Very high (robust AI + IoT)
Security	Low	Improved (real-time tracking)	High (biometric security)	Very high (AI + Blockchain)
Scalability	Low	High (cloud integration)	Moderate	High
Transparency	Poor	High (real-time logging)	High (secure authentication)	Very high
Key Gaps	Prone to fraud	High cost, maintenance issues	High cost, lighting issues	Integration and cost challenges
Future Focus	N/A	Low-cost solutions	Improved AI for rural use	Blockchain, mobile accessibility

Hybrid approaches, [1] incorporating GSM and IoT with face recognition, have shown a huge amount of promise. Hybrids were able to demonstrate the effectiveness in curtailing fraudulent activities by enhancing smart card technologies, automated dispensing mechanisms, cloud infrastructure, and biometric verification. These hybrid systems also allow for a reliable, secure and scalable automation of PDS.

III. SUMMARY OF THE OUTCOMES

A number of studies indicate that automated ration distribution systems could possibly correct the age-old problems of incompetence, nepotism, and irregularity quite prevalent with traditional PDS. [11] Researchers have made interesting strides in security, accuracy, and transparency of ration distribution operations through incorporation of technologies like RFID, IoT, biometric authentication, facial recognition, etc. This section brings out the main results from these technological developments and how they affect modernization within PDS. Examinations showed that the essential commodities were delivered through PDS, though such systems had often been plagued by inefficiencies. Newer technologies like biometric-based identification and Internet of Things seek to address these issues by automating some parts of the system. Different methods for the automation of ration distribution schemes are compared below.

We compare and contrast several ration distribution schemes' accuracy.

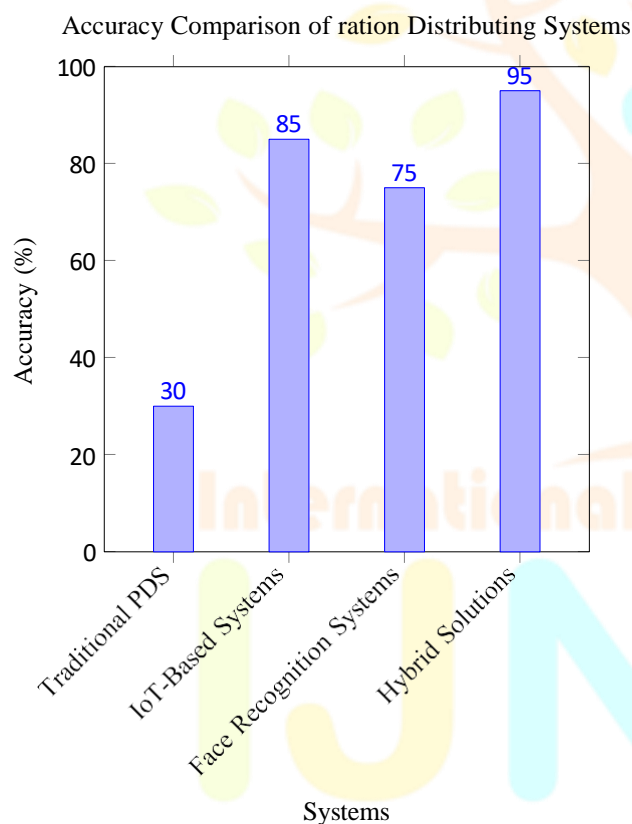


Fig. 1. Accuracy Comparison of Different Ration Distribution Systems

A. Increased Efficiency and Accuracy

The principal consequence of the automation of PDS distribution systems is therefore phenomenal leap in operational efficiency. Since these traditional PDS systems are extremely manpower-intensive, they tend to suffer from delay, human error, and arbitrariness in commodity measures. However,

automated systems have no such weaknesses, as solenoid valves, microcontrollers, and load cells ensure proper measurement and dispensation of commodities. It is because of the considerable reduction in errors resulting from under- or overweighing of products that automation has ensured full entitlements for its beneficiaries.

Apart from that, embedded technology and Internet of Things-based solutions improved streamlining the distribution process and, hence, decreased waiting time and increased the transaction speed. Real-time reports regarding levels of stock and transactions allow government authorities to easily monitor the system and enhance the efficiency of PDS.

B. Transparency and Fraud Reduction

Corruption and fraud have always been major problems of traditional PDS as shops and middlemen falsify records, create fake entries, and siphon ration supplies into the black market. The reduction of these malpractices has immensely gone hand-in-hand with the innovation of automated technologies. Here, the scope for human interference is almost absent as verification and dispensing are all automated. RFID and biometric authentication- facial and fingerprint recognition protect ration entitlements from unauthorized access. Apart from preventing unauthorized access, this reduces the chances of having duplicate ration cards. The integration of GSM and IoT modules has made it possible to track every real-time transaction such that every stage of the distribution process can be traced. As a result, such a system has become so transparent, and making fraud go undetected becomes difficult. The integration of the GSM and IoT modules into this system has enabled real-time tracking of each transaction, and the former guarantees that every stage of the distribution process is tracked and recorded. This system, therefore, has become even more transparent than before, making the fraudulent activity even more difficult to go unnoticed. Installing an automated ration distribution system has been shown in many studies to have considerably reduced fraud and corruption. Transparency was further promoted in the process due to real-time updates of data and transaction logs that made every step of the distribution chain accountable.

C. Improved Security and Authentication

One of the significant impacts facial recognition technology has on ration distribution is the improvement in security and authentication procedures. Face recognition technologies simply replace physical cards or tokens, which can be misplaced or stolen and then altered so easily, with a beneficiary's specific facial features for verification purposes. This makes it more reliable and secure to identify people with such systems.

These have lifted the accuracy levels of the face recognition systems due to application of machine learning algorithms and the face detection techniques, which include the Haar Cascade and Histogram of Oriented Gradients (HOG) even in difficult situations with changing lighting and facial expressions. Face recognition is thus a feasible alternative for PDS authentication, especially in remote locations where the

use of physical tokens or fingerprint authentication might not be viable. Also, with the integration of face recognition with IoT-based technologies, all transactions made are documented and authenticated. This contributes to general security in ration distribution as risks pertaining to fraud and identity thefts are reduced.

D. Real-Time Monitoring and Data Management

The two advantages of an IoT-based ration distribution system are real-time monitoring and central data management. Traditional PDS systems are usually characterized by a lack of transparency coupled with a huge disparity between records held in government agencies and ration shops. This gap has permitted corruption and poor management to thrive in these systems. In return, computerized systems employing Internet of Things technologies provide real-time updates on stock levels, transactions, and user activities. With this feature, authorities can monitor the system in real time and take prompt action should anomalies occur. Data centralization also makes better control and planning possible since one can monitor consumption trends and forecast demand, stopping stock outages or shortages.

Moreover, data automation erases a lot of manual and error-prone record-keeping done by people. Additionally, the systems assure that the data will be correct and unbreachable by storing the transaction logs and other information about the beneficiaries in safe databases.

E. Enhanced Accessibility for Beneficiaries

Besides the above advantages, automation has expanded accessibility for recipients with respect to PDS, especially for persons living in yet more remote and inaccessible places. It was often hard for people who live in places which are more or less far away from town centers or for people with mobility issues to travel to the ration shops at the appointed times. It is because IoT-integrated automated systems allow variable distribution and some can even provide commodity rationing at any time of the day. This face recognition technology makes access easier while allowing authentication. Instead of tangible tokens or cards, the faces of beneficiaries constitute their identification as the process becomes more user-friendly through its streamlining. It would help the aged or illiterate who would not be able to make use of the normal card-based systems.

F. Reduction in Manual Labor and Human Intervention

Some important distribution steps such as weighing, dosing and validation were automated in this system which significantly reduced the effort to be put in by a human. This has greatly decreased the operational cost of the ration shop and lessened the likelihoods of corrupted and human mistakes. As some individuals, who are isolated and prejudiced and lack proper knowledge, are used for this allocation procedure, the reliance on them will be low since the automated technologies are much more precise than their corresponding human agent. Moreover, transaction automation and real-time data updates

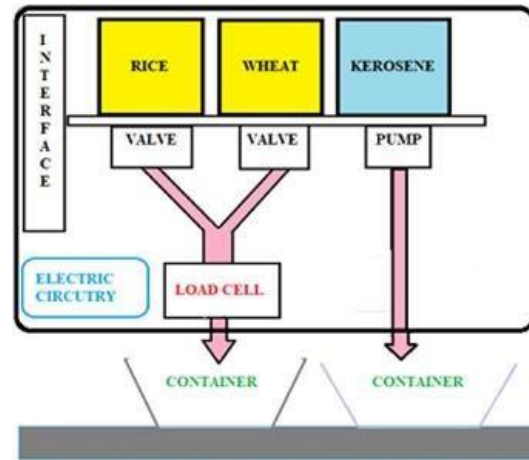


Fig. 2. Dispensing System

reduce the necessity of human intervention in record-keeping and monitoring. Instead of an audit and inspection cost, government organizations can save their money through utilizing automated technologies for acquiring accurate report and data. Significant security, accuracy, efficiency, and transparency improvement has been seen through the initiation of automated technologies for ration distribution. Most of the problems in traditional PDS, such as fraud, corruption, and inefficiency, have been well overcome through these methods, and beneficiaries do not think twice before making use of the ration distribution carried out through these means. For the complete exploitation of such systems on an enlarged scale, more research and development activities are still required because some of the issues, such as cost, technical complexity, and scalability, are still continuing to be there.

IV. EXISTING RESEARCH GAPS

Despite such significant progress being made in the area of PDS automation through the integration of embedded systems, biometric authentication, face recognition, and the Internet of Things, there are still quite a few research gaps that prevail and must be overcome in order to allow for such systems to be adopted and implemented more widely, especially with large-scale, national deployments. The knowledge gaps provide some much-needed opportunities for understanding study gaps to direct future developments in automated ration distribution methods.

A. High Initial Setup Costs

One of the major obstacles to the widespread implementation of automated ration dispensing systems is their high setup cost. Many of these technologies such as IoT devices, RFID systems, face recognition cameras, microcontrollers, load cells, and other automated dispensing equipment require high monetary investments. It will be too expensive to install these technology across thousands of ration shops in a country like India where most of the population resides for large-scale

PDS systems. The cost also includes the infrastructure that will be required to run these systems, such as cloud-based databases that are reliable for storing and managing data, the secure internet that will relay real-time information, as well as the hardware required for automation. These solutions are not easy to implement for governments and local authorities due to the high costs associated with setting them up, integrating them, and maintaining them on an ongoing basis, which can be challenging in rural or impoverished areas.

Further research is needed to come up with less expensive alternatives that could offer at least similar levels of security and efficiency for a much lower cost. Closing this gap in research, automation can be more readily implemented if hardware less expensive options and exploit existing infrastructure are used in the most effective ways possible.

B. Technical Complexity and Maintenance

The most significant challenge is the high technical complexity of the newest generation of automated ration distribution systems. While it may significantly raise productivity and lower fraud, these systems are highly technical in nature and require a minimum amount of technical competence to work on and keep functional. These include hardware control-for instance, facial recognition systems, load cells, and IoT modules-ability to resolve software issues and data security protocols.

PDS operators tend to lack technical know-how in managing such systems, especially in rural areas and areas hardly accessible. Small technical setbacks could freeze operations and lead to several days of delay in distribution and potentially total system break-down. Automated systems are also susceptible to software bugs and hardware failures that would mean improper transaction logging and dispensing errors.

This also entails further research into user-friendly interfaces and low-maintenance systems that are manageable even by amateurs with the least technical competence. Other areas for research include self-healing and remote diagnostic systems that can distinguish between problems that require solutions, with such solutions specifying the sources of problems within the system itself.

C. Scalability and Integration

Much of the automated ration distribution systems that have been devised and piloted up to this day has only been implemented on small regional scales, often as pilot studies in one or two ration shops or specific locations. There is a dearth of research regarding scaling these systems into a national scale, despite the promise these systems have shown in boosting efficiency and openness.

One of the main challenges is the coordination between vast, mechanized systems across thousands of ration shops. Each one is different in terms of its level of infrastructural development, technology, and connectivity. For such a system to be implemented across thousands of shops alone, which service millions of beneficiaries, integration would need to occur both horizontally-across different shops in different areas-

and vertically-from the ration store to centralized government servers.

The requirement for technology interoperability adds another layer of complexity to scalability. Applications that use RFID authentication may need to interface with applications using facial recognition or other biometric methods. One such area of wide research gap still remains in the ability to seamlessly operate data across all of these devices and service centralized databases dealing with floodgates of real-time data pouring in from thousands of location-specific places. There is a serious research need on cloud-based systems along with scalable architectures in order to manage huge data in an efficient and fast manner. Moreover, such research on the compatibility of various IoT and biometric technologies is required for stable and efficient functioning in very wide implementations.

D. Connectivity and Infrastructure Issues in Rural Areas

Most PDS users reside in rural and remote locations with questionable connectivity and infrastructure. Automated ration distribution systems usually rely on central databases for user authentication and send real-time data via GSM, Wi-Fi, or other networks. Internet access is, however, not dependable and inconsistent in most rural sites, and could easily shut automated systems down. This deficiency in infrastructure, apart from affecting the dependability of transactions, creates hassle for the system in updating and interacting with central servers, which may lead to variations between local and central records. In addition, frequent power outages in these remote locations may affect the working of these systems and also may delay rations.

Offline-compatible systems that could work efficiently in connectivity-poor areas require additional research. Such a gap could partly be bridged by solutions that ensure local data caching followed by regular syncing with central servers once connectivity is restored. In the same way, ration distribution could be maintained in areas with unreliable power supplies through the use of devices that could operate at low power or on renewable energy sources.

E. Privacy and Data Security Concerns

Privacy and security involving sensitive personal data are becoming increasingly a concern because of the growing dependency of automated ration distribution systems on biometric data, such as fingerprints and facial recognition for user authentication. These data include transaction records and personal information belonging to millions of beneficiaries besides biometric data. Large volumes of data are collected and transferred because of the integration of cloud-based and IoT systems.

This raises several issues regarding the methods of data storage, access control, and security measures adopted to prevent misuse, unauthorized access, and leakage of data. As systems become increasingly complex in terms of encryption, full-fledged security mechanisms are required that enforce both confidentiality and integrity for biometric data. The ethical and

legal framework of using biometric data in public systems is still under development process and with many open issues regarding the ownership and protection of personal data.

Safe data transmission and storage mechanisms, such as encryption end to end, blockchain technology for unbreakable transaction recording, and privacy-preserving algorithms, are yet to be researched. Also, the low research base on regulatory frameworks that ensure that biometric data is used in an ethical manner and ensures rights of the beneficiaries.

F. Inclusivity and Usability

Although the biometric authentication technologies, such as face recognition, provide maximum security, not all of the users will use them. For example, face recognition algorithms fail to recognize people with disabilities or scars on their faces, and people hiding their faces because of religious or some other reasons. Similarly, aged skin fails to work for older people while using fingerprint scanners. This poses questions on whether such systems consider the issue of inclusivity and whether some groups might not have the power to use their rights. More inclusive biometric systems or hybrid models are required that are currently furnishing substitute techniques for authentication to ensure that no one is denied his ration. Usability studies for adapting these technologies toward demands and constraints of the users become extremely important while considering rural and underprivileged groups.

Summarily, while much has been improved by the use of automated ration distribution methods in PDS, so many questions are still left unanswered. Closing these gaps will improve scalability, security, affordability, and inclusivity. Future studies will have to be along the dimensions of cost effectiveness, maintainability, and flexibility with chances that this solution may be adaptable to the problems caused by the problems themselves created by data security problems and rural infrastructure issues. Only then will actual potential in the automated PDS system be realized as a guarantee to ensure both efficiency and fairness in distributing necessities.

V. FUTURE SCOPE

The use of deep learning algorithms and AI technology [12] can improve the resiliency and accuracy of the system in illumination, facial expressions, and occlusions. Conversely, it is equally possible to apply such sophisticated models of AI, like convolutional neural networks, to ensure wide deployment of the system. Automatic ration distribution systems are being looked into with regard to availability and efficiency.

Low-cost solutions are required in less developed areas where the resources are not adequate and much knowledge of technology is also not in hand; because most automation systems are very expensive. It would be good if cheaper hardware and software were to be found by researchers, so that they can be compared with benefits at a significantly lower cost to automation. Perhaps findings about cheaper alternatives like sensors, open-source solutions, designs requiring less maintenance and professional inputs may help in this regard.

Another innovative step in safe-guarding data in automated ration distribution systems is through the adoption of blockchain technology, where decentralized, hack-proof ledgers are possible for use in transaction recording with a verifiable and auditable record of transactions that thwarts fraud and data manipulation. This is especially critical in the PDS system of present-day life, where frequent alterations and manipulations of data are common and undermining the system.

Mobile access can make high-end infrastructure in ration distribution systems accessible for services to rural communities. Mobile-based solutions, for example, are in the form of apps or SMS-based systems that enable beneficiaries to receive ration distribution services through phones that are more common than advanced biometric devices in rural areas. This might bring automated services to a wider customer base thus benefiting the most alienated populations

CONCLUSION

The scope of automation technology for the PDS under India is extensive, and therefore, the correct approach has the potential to efficiently sort out fraud, corruption, and inefficiencies in the system. Cases such as integration of IoT along with facial recognition, for biometric authentication, and blockchain technology can bring a fundamental change in the traditional PDS paradigm. Such approaches support transparency: data is scanned with minimal human interference and is monitored in real-time and logged. Through the use of IoT, the authorities can monitor stock levels and transactions and prevent any manipulation or access. By means of facial recognition, beneficiary authentication security is greatly enhanced. There is no need for any physical ration card. It is decentralized and tamper-proof ledger of all the transactions. Virtually fraud has become impossible with integration of blockchain technology. However, many such serious challenges still exist: The costs remain high and technical in complexity, and at the same time, problems concerning scalability, especially in regions as large as in India. Technical know-how and infrastructure also may be limited in remote or rural regions, making them even more inconvenient to implement. Overall, while automated ration distribution systems do hold promising solutions for the deficiencies of the PDS-in terms of efficiency, fairness, as well as transparency-it is important that much more research must be done to bring these into an affordable, scalable, adaptable form. Only then can such technologies be applied effectively at scale to benefit various geographical and socio-economic contexts of the country, across India.

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