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Blockchain in Indian Public Distribution System: a conceptual framework to prevent leakage of the supplies and its enablers and disablers

Himani Mishra
Department of Management, Indian Institute of Foreign Trade, New Delhi, India, and

Prateek Maheshwari
Department of Management, Indian Institute of Forest Management, Bhopal, India

Abstract

Purpose – The purpose of this paper is to propose a conceptual framework for the application of blockchain in the Public Distribution System (PDS) in India to manage the supply of food grains to the targeted beneficiaries. The framework will help prevent diversions and leakages of grains at the warehouse and Fair Price Shop (FPS) level. The paper also identifies the enablers and disablers in the context of the framework.

Design/methodology/approach – This paper will firstly review the previous literature in PDS and blockchain-enabled agricultural and food supply chains. The study then proposes a framework that could be implemented in the PDS in India using blockchain technology.

Findings – The proposed framework provides an effective way to combat corruption, exclusion errors of targeted beneficiaries, leakage of PDS food grains and is cost-effective. The identified enablers and disablers give an insight into the application of blockchain in PDS in India.

Research limitations/implications – The research work may have implications for the Ministry of Food and PDS (Central Government), Food Corporation of India and State Governments to manage the supply of the grains more efficiently and effectively.

Originality/value – The current study caters to the implementation of blockchain technology starting from the warehouse level to the FPSs and consumers and simultaneously connecting them to concerned authorities to ensure transparency and accountability.

Keywords India, Qualitative, Framework, Literature review, Corruption, Leakage, Public Distribution System, Food supply chain, Blockchain, Industry 4.0, Exclusion errors, Agricultural supply chain

Paper type Research paper

1. Introduction

Public Distribution System (PDS) is India's major safety net program that guarantees food grains to all people through a network of over half a million Fair Price Shops (FPSs) (Biswal *et al.*, 2018). With an outlay of INR 1,132bn, the system accounts for 1.3% of gross domestic product (GDP). Essential commodities such as rice, wheat and pulses are supplied to approximately 180 million families at subsidised prices, costing INR 950–1120bn (Kumar *et al.*, 2017). In the earlier years, PDS was entitled to all the people of the country, but due to increasing pressure, the government then introduced Targeted PDS (TPDS) to specifically

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target Below Poverty Line (BPL) families (Das, 2015). Ensuring consistent access and food supply to all the households has been a challenge for India since independence. Though the production and procurement of food grains have improved in a formidable way, the institutional arrangements, delivery mechanisms and infrastructure facilitating the supply are still a matter of concern (Mane, 2006).

PDS is recognised for its effort in emerging economies such as Bangladesh, Cambodia, Pakistan, where it has helped get more girls into education (Kattumuri, 2011). Brazil "Bolsa Familia" scheme has performed better than other welfare schemes of the country (Kattumuri, 2011).In India too, PDS is recognised for its efforts in alleviating hunger. However, it is often criticised for large scale corruption. In 2018–2019, the Government of India spent US$60bn on welfare subsidies majorly through PDS; however, 40% was lost due to corruption, misuse and inefficiencies of PDS (Jaffer *et al.*, 2020). The system faces exclusion and inclusion errors of beneficiaries, rampant leakages, wastages, corruption, pilferage and diversion of supplies in the market. Defective delivery mechanisms, fake stock-outs, bogus supply entries in ration cards and poor quality of grains plague the system (Das, 2015). For every rupee transferred to the poor, the state spends an additional Rs 3.65 (Gupta and Misra, 2018). Although 30% of food subsidy gets transferred to the beneficiaries, the rest comprises the cost of illegal diversions of food grains (43%) and operational costs (23%) (Pawar *et al.*, 2020). Subsidised grains create an incentive for agents to leak good in the open markets. Agents exploit the difference between regulated and market prices (Pawar *et al.*, 2020). Poor governance, weak administration, inadequate monitoring by higher authorities and government, and lower commission rates for the FPS shop owners result in rampant corruption at the later PDS supply chain levels, including FPS shops and warehouses. (Kumar *et al.*, 2016, 2017).

National Food Security Act of India 2013, which aims for ensuring food security for all the people of the country, makes a strong case for using information technology (IT) solutions, end-to-end computerisation of PDS and digitisation at all the levels (Gulati and Saini, 2015). NITI Aayog, the apex policy-making body of the Government of India, advocates the use of blockchain in PDS (Singh *et al.*, 2020)

Blockchain is a scattered peer-to-peer ledger, encompassing an ordered set of linked and simulated data blocks (Drescher, 2017). Blockchain finds its application ranging from the financial sector institutions such as banks to supply chain, health care, retail management and manufacturing (Hughes *et al.*, 2019). Blockchain usage varies from industry to industry. In the public sector, it is used for land registry, in health care for patient record management, in the oil and gas sector to enable digital supply chain (Deloitte ASSOCHAM India, 2017). The countries such as Australia, China, Japan, the USA, UK, ace in the application of blockchain technology, using blockchain in various functions. United Arab Emirates envisions to make government departments completely paperless using blockchain technology (Sharma, 2019). In India, the banking and financial sector aces in the adoption of blockchain technology followed by other industries, such as health care, retail and manufacturing (NASSCOM Avasant, 2019). Seven Indian banks have joined JP Morgan Blockchain Network, and India's public sector is emerging as a significant consumer of blockchain solutions in the coming years (Das, 2019). Over 40 initiatives are being executed by the Indian public sector using blockchain. These are related to the land registry, securing digital certificates and governance. More than 50% of Indian states are involved in blockchain initiatives and have emerged as key drivers for blockchain adoption in the country (NASSCOM Avasant, 2019). Owing to its benefits of transparency, accountability, immutability, traceability and many more, blockchain is emerging out as favoured option in the food supply chain across the world (Bailis *et al.*, 2017; Hawlitschek *et al.*, 2018; Salah *et al.*, 2019).

IBM offers blockchain services for food supply chain stakeholders via its blockchain platform (IBM Blockchain, 2018), Many agri start-ups based in countries such as the USA, Australia, India, Great Britain are offering blockchain services ranging from crop insurance, product traceability to financial transaction and optimisation of the supply chain (StartUS Insights, 2018). Walmart is known for its proactive role in blockchain adoption in the food supply chain (Tan *et al.*, 2018) to improve food products traceability and assure end consumers about the safety of products sourced.

Blockchain can serve as a potential solution for addressing the rampant corruption in PDS of food grains. The decentralised database, checks and controls over each transaction and movement and continuous vigilance of higher and middle authorities will be the potential benefits of the application of blockchain in PDS. Adopting blockchain technology can help create a trusted information exchange facilitating the visibility of supply chain (Singh *et al.*, 2020). This paper proposes a framework for the application of blockchain technology in the PDS in India, which disperses the subsidised grains to the targeted beneficiaries throughout the country. The framework will facilitate checking and combating diversions and leakages of grains at the warehouse and FPS level.

The paper discusses the PDS and reflects upon the system's problems and challenges in Section 2. The paper then elaborates on blockchain technology and how it finds its application in the agricultural and food supply chains across the world in Section 3. Section 4 highlights the previous literature across the themes of PDS , blockchain, blockchain in supply chains and blockchain in agricultural and food supply chains. Sections 5 and 6 highlight the observed research gap and the research methodology opted for the paper. The conceptual framework is then proposed explaining the application of the framework across "three blockchain scenarios" in Section 7. Enablers and disablers for the framework are then identified in Section 8. The paper then discusses the results, practical implications and concludes with limitations and future research scope in Sections 9–11.

2. Public Distribution System: its problems and challenges

The PDS was launched as a program to fulfil food grain shortage during the early years after Independence. However, due to wide criticism for its urban prejudice, the system was later streamlined by introducing the TPDS in June 1997 (Kishore and Chakrabarti, 2015). It was meant to provide impoverished families access to food grains at a reasonably low cost to improve their diet standards and achieve food security. The National Food Security Act also focuses on providing food security by expanding the PDS (NITI Aayog, 2016) (Gupta and Misra, 2018).

With the enactment of the National Food Security Act, the PDS became even more crucial. Considering the achievements of TPDS published in the Economic Survey (2018/2019), the digitisation of ration cards and online sharing of food grains is completed in all states and union territories. Computerisation of the food supply chain is completed in 25 states, and transparency portals have already set-up in all the states and union territories, whereas intrastate portability is operational in eleven states (Economic Survey, 2018/2019). However, PDS in India is still facing the following problems and challenges:

2.1 Problem 1: Bogus ration cards and inclusion/exclusion errors

Exclusion errors could translate into malnutrition and starvation for the food-deprived poor (Mane, 2006). The proportion of households having Antyodaya Anna Yojana (AAY)/Annapurna/BPL Cards is too high when compared to the poverty rates. As per the Indian

Human Development Survey (IHDS) 2004–2005 and 2011–2012 surveys, the percentage of the underprivileged came down from 38.4% in 2004–2005 to 21.3% in 2011–2012 using the *Tendulkar Committee Poverty Line* based on the consumption data. The proportion of non-poor went up from 61.6% to 78.7% (NITI Aayog, 2016). Although poverty is lessening, the proportion of households with AAY or BPL cards has increased slightly, thus indicating bogus ration cards.

Various evidence of inclusion and exclusion errors come from various states of India. Exclusion errors for Andhra Pradesh and Maharashtra stood at 22% and 49%, respectively; however with passing years, it has significantly reduced (Mane, 2006). In Rajasthan, 44.3% of the poor population is covered under PDS scheme, however out of this population, 23.5% is non-poor population (Overbeck, 2016).

2.2 Problem 2: above poverty line scam

Some economists point out that the main source of ongoing leakages is the above poverty line (APL) quota (Dreze and Khera, 2011). As much as 58% of subsidised grains failed to reach the target group (Gulati and Saini, 2015). This high leakage comprised an estimated 21% diversion to APL households, and 36% of grains were siphoned off from the supply chain (Pal *et al.*, 2019). The inclusion of non-poor household proves detrimental for the PDS (George and McKay, 2019). According to National Sample Survey, this leakage is around 67%, whereas IHDS says it is around 56% (Dreze and Khera, 2015). Using panel data estimation techniques, Overbeck (2016) confirms that the rise in the APL segment in total grains provided by the central government is about 25% (Overbeck, 2016).

2.3 Problem 5: aadhar-based biometric authentication

According to a report, 85% of the food grains in Jharkhand was estimated to be siphoned – off by corrupt middlemen in 2004–2005. Since late 2000, the system improved due to a series of reforms initiated by state governments, especially pioneering PDS initiatives of Chhattisgarh state (Dreze *et al.*, 2017).

Aadhar-based biometric authentication (ABBA) was first launched in Jharkhand due to rising cases of bogus ration cards. However, the system did not work well because Aadhar seeding was not proper, fingerprints did not match and the internet connectivity was poor (Dreze *et al.*, 2017). Many beneficiaries also complained about skipping of month's quota either due to fraud or interruption in the supply chain. The major form of malpractice undertaken is *katauti* (giving lesser grains), which ranged from 0% to 20%, depending on the education and level of awareness of the cardholders. Although *katauti* has been reduced after the biometric authentication implementation, it is still rampant (Dreze *et al.*, 2017). There are issues related to portability, where beneficiary could collect his grains from any FPS shop (Sharma and Gupta, 2017)

2.4 Problem 4: leakage estimates

PDS leakages refer to rice and wheat released by the Food Corporation of India (FCI) that does not reach end-users. Investigating irregularities after public interest litigation was filed, in the public distribution, it was found that 80% of the distribution fraud occurs much before food grains reach the ration counters (Lal, 2015).

National Sample Survey Organization (NSSO) surveys estimate 28.5% nationwide PDS grains leakage in 2011–2012. IHDS estimates it to be 32% (Dreze *et al.*, 2017). State-wise records reveal that leakage of grains is reducing, but there is a long way to go (Kumar *et al.*, 2017). NSSO surveys report Odisha leakage of PDS grains to be 11.4%, whereas for Bihar at 12.5% (Kumar *et al.*, 2016, 2017). The states of Chhattisgarh and Jharkhand stand at 9.3%

and 44.4% of estimated leakage, respectively (Gupta and Misra, 2018). In Uttar Pradesh, the most common form of leakage is fake stock-outs at shop levels. Only 77%–88% of households of Uttar Pradesh receive entitlements, but the situation is slowly improving for better (Gupta and Misra, 2018; Nagavarapu and Sekhri, 2016).

2.5 Problem 5: high costs of food subsidy

The cost of food subsidy has risen to high levels for many countries pushing countries to fiscal unsustainability (Pawar *et al.*, 2020). In 1996–1997, the total cost of food subsidy in Egypt amounted to the US$1.1bn, which has increased exponentially with passing years. As of 2018, France spent 31% of its (GDP) on welfare schemes, whereas for the USA, the highest amount of expenditure in 2011 federal budget was welfare expenditure (Jaffer *et al.*, 2020). Food subsidy reached a whopping level of Rs. 72,283 Crore in 2011–2012 for India. Increase in procurement price was the main contributor to the increase in the economic cost of food grains responsible for rising food subsidy (Sharma, 2012). However, efficiency in operations of handling of grains can help in reducing costs of dispersing grains by retaining the current mechanism of PDS (George, 1996). This calls for combating leakage of grains, and inclusion and exclusion errors.

3. What is blockchain: overview and its application in food supply chain

Blockchain, a novel fourth industrial revolution technology, is expected to disrupt the way industries and economies work. Known as the backbone technology behind Bitcoin, blockchain has the potential to transform multiple industries and make processes more democratic, secure, transparent and efficient (Deloitte ASSOCHAM, 2017). It is believed that the global markets for blockchain technology will be US$20bn by 2024 (Louis, 2018).

Blockchain is a distributed database where all the parties involved have access to the database. No single party controls the blockchain. Complete audit trail of each informational transaction can be traced. There is no intermediary involved; therefore, parties can directly contact each other. Once any transaction is recorded, it cannot be altered (Iansiti and Lakhani, 2017). Any alteration would require each party's permission, making it almost impossible to modify the records falsely. Blockchain works on computational algorithms and models; therefore, such systems could be developed that are acceptable to all the parties involved in blockchain (Tapscott and Tapscott, 2017). Potential blockchain benefits include trust, cost reduction, automation, processing speed, streamlined process and disintermediation (Hughes *et al.*, 2019; Casino *et al.*, 2019). With the platform such as blockchain, no cost would be incurred for establishing trust thus facilitating risky transactions and sharing sensitive information

Each member (stakeholder) on blockchain system stores copy of all previous transaction ever executed through the given system. However, no single party/node is the owner of data, which shows that it is not a centralised system. As each activity in the system is visible and auditable by all members, this decentralised system creates trust. For any transaction to happen, a consensus protocol is followed means consensus of nodes that agree upon the issue which ensures its validation and authorisation. The blockchain-based system does not require a mediator or third party for a transaction, leading to lower transactional cost and enabling peer to peer communication. These transactions are also irreversible (Bailis *et al.*, 2017; Hawlitschek *et al.*, 2018; Quieroz and Wamba and Quierzo 2019; Hughes *et al.*, 2019).

There are two types of studies that can be observed in the blockchain literature in the food supply chain. Firstly, that discuss the effectiveness of blockchain solutions already implemented in food supply chains (Tan *et al.*, 2018; Baralla *et al.*, 2019; Bumblauskas *et al.*, 2019) and secondly, the studies which discuss the use cases where blockchain technology could be implemented to improve efficiency and traceability (Accenture, 2018; Sunny *et al.*, 2020). Walmart inaugurated Walmart Food Safety Collaboration Centre in Beijing, China, in 2016 to improve food traceability in China (Tan *et al.*, 2018). Two most innovative ventures of Walmart's blockchain are in the supply chain of pork in China and mangoes of South America. Such supply chain aims to improve traceability in the supply chain, ensure food safety, improve recall speed, maintain a good reputation among consumers and reduce cost (Tan *et al.*, 2018). Walmart already uses blockchain in India for end-to-end traceability of shrimp sourced from Andhra Pradesh and shipped to the USA (Aggarwal, 2019). Punjab Agri Export Corporation (PAGREXCO) will deploy blockchain technology to undertake certification and traceability of seed potato right from nucleus to seed level (harvest) in upcoming years (Roy, 2019). Europe uses blockchain technology in the food supply chain that uses the farm to fork model for ensuring the traceability of various food products (Baralla *et al.*, 2019). Earlier the US regulators needed traceability of food products that needed to trace the product one step forward and one backward, but with the introduction of blockchain technology, the whole supply chain of any product could be traced in the real-time (Bumblauskas *et al.*, 2019).

Various authors have suggested that blockchain can be implemented in some food supply chains to increase their demand among the consumers by providing a detailed history of how those goods are sourced (Sunny *et al.*, 2020). Accenture (2018) presented a detailed report to assess blockchain's feasibility to enable end to end supply chain traceability of four food commodities – Indonesian Tuna, Thai farmed shrimp, Brazilian Soy and Brazilian beef. These commodities enjoy significant market size and have a great social and environmental impact (Accenture, 2018).

4. Literature review

A detailed literature review was carried out. Databases such as EBSCO, Proquest, JStor, Emerald and search engine Google Scholar were used for accessing papers. Papers published in peer-reviewed journals and the reports published by Government and renowned organisations were selected for the literature review. Key terms used to search and extract the papers were blockchain, blockchain in the supply chain, PDS and blockchain in agricultural supply chains and food supply chains. The papers of all these themes are analysed to see and derive the conclusions about blockchain in PDS in India, simplifying logistics from the warehouse to the targeted consumers.

4.1 Blockchain

Blockchain offers significant advantages of immutability, transparency, security, trust and computational logic (Casino *et al.*, 2019; Hughes *et al.*, 2019; Iansiti and Lakhani, 2017). Li *et al.* (2018) concluded after an extant literature review that "how" of blockchain is being focussed more in research, the focus needs to be shifted to "what" and "whyespecially in the context of business organisations. Besides Bitcoin, blockchain is applicable in the supply chain, finance sector and data record management (Huumo *et al.*, 2016). Tang *et al.* (2020) discuss ethical issues of blockchain and provides a systematic study on socio-technical challenges that will be faced while implementing it. In countries where blockchain is famous such as the USA and European Union Countries, blockchain faces some regulatory issues (Yeoh, 2017). However, in the Indian context, where blockchain is still in infancy stage the significant consumer of blockchain in India is banking and financial sector, however its fast-expanding in other sectors such as logistics, public sector and logistics (NASSCOM Avasant, 2019) (Table 1).

4.2 Public Distribution System

PDS is inflicted with problems of leakage, diversion of supplies and corruption. Though ABBA has been initiated for purchasing of grains from FPSs, but still, there are many setbacks faced by the system (Dreze and Khera, 2015; Dreze *et al.*, 2017). Poor residents who lack documentation find it challenging to get their identities verified (Sachan, 2018). The Economic Survey (2018/2019) highlighted the TPDS statistics and its related aspects (Economic Survey, 2018/2019, Volume 2).

Technology-based reforms have been initiated in India's various states to revamp PDS (Kumar *et al.*, 2016; Gupta and Misra, 2018). These include digital ration cards, usage of smart cards, monitoring movement of grains with Global Positioning System, message alert on the arrival of grains at the shop (Verma *et al.*, 2018). For instance, Centralized Online Real-Time Electronic (CORE) PDS in Chhattisgarh, which received countrywide appreciation for its IT approach (Chhotray *et al.*, 2020).

Researchers have investigated IT approaches that can be implemented in PDS. Agent-based social simulation of PDS using IT and an automated PDS approach using biometric-based authentication and microcontroller networking system are two such approaches (Verma *et al.*, 2018; Hitaswi and Chandrasekaran, 2017). The storage and warehousing of grains could be made efficient with Radio Frequency Identification (RFID) in PDS (Biswal *et al.*, 2018). The 11th five-year plan proposed that RFID be used in the PDS (Kattumuri, 2011).

The use of information and communication technology (ICT) led to efficiency, transparency accountability and reduced corruption; however, there is a long way to go. Lack of IT competence of ground-level workers, lack of incentive and lack of infrastructure yielded fewer returns as it was expected to yield (Sharma and Gupta, 2017). Before implementation of blockchain at large scale, robust infrastructure is required at the grassroots level. This would require ABBA of all the targeted beneficiaries (Sachan, 2018) to avoid inclusion and exclusion errors (Mane, 2006), functional separation of various PDS operations to enhance efficiency (George, 1996) proper and secured storage of data, availability and proper functioning of Point of Sales (PoS) machine (Dreze and Khera, 2015), internet availability till the last mile (Deloitte ASSOCHAM, 2016), computerisation at all levels of PDS (Economic Survey, 2018/2019, Volume 2) and setting up of vigilance committees to leakages and corruption (Mane, 2006) (Table 2).

4.3 Blockchain in supply chains

The researchers have realised that blockchain is not a mere buzzword and can significantly impact business organisations and is a disruptive technology for supply chain management (Quieroz and Wamba, 2019). Blockchain and supply chain transparency was found to be the

S. No.	Paper/Report	Description
1	NASSCOM Avasant (2019)	Scope of blockchain in public sector industries
2	Iansiti and Lakhani (2017)	Benefits of blockchain
3	Hughes *et al.* (2019)	Extensive Literature Review of Blockchain
4	Linda *et al.* (2019)	Global Survey of Blockchain in Organisations
5	Tang *et al.* (2020)	Ethics of blockchain and research directions
6	Yeoh (2017)	Regulatory issues in blockchain technology
7	Huumo *et al.* (2016)	Systematic Review on blockchain
8	Casino *et al.* (2019)	Systematic review on blockchain-based applications

Table 1. Description of papers related to "blockchain" theme

S.No.	Paper/Report	Description
1	Dreze and Khera (2015)	Leakage and above poverty line quota in the Public Distribution System in India
2	Dreze *et al.* (2017)	Setbacks of aadhar-based biometric authentication in the Public Distribution System
3	Economic survey (2018/2019), Volume 2	Facts related to the Public Distribution System
4	Hitaswi and Chandrasekaran (2017)	Agent-based Social Simulation Model in PDS
5	Sharma and Gupta (2017)	CORE-PDS of Jharkhand
6	Kumar *et al.* (2017)	PDS in Odisha, India
7	Kumar *et al.* (2016)	PDS in Bihar, India
8	Gupta and Misra (2018)	PDS in Uttar Pradesh, India
9	Chhotray *et al.* (2020)	PDS in Chhattisgarh and Jharkhand in India
10	Biswal *et al.* (2018)	RFID in PDS
11	Verma *et al.* (2018)	IoT (Internet of Things) in PDS
12	Das (2015)	Evolution of PDS in India, as its inception
13	George (1996)	PDS and Food Subsidy in India
14	Mane (2006)	TPDS and exclusion errors
15	Kattumuri (2011)	TPDS in India

Table 2.
Description of papers related to the "public distribution system" theme

main predictors in blockchain adoption in the empirical model tested in a developed country (USA) and a developing country (India) (Wamba *et al.*, 2020). In the Indian context, a model for the adoption of blockchain in the supply chain is developed integrating three adoption theories that are technology acceptance model, technology readiness index and the theory of planned behaviour. Their empirical findings highlighted that supply chain practitioners perceive blockchain adoption free of efforts and will implement it to improve supply chain effectiveness (Kamble *et al.*, 2018a). In a similar study conducted in Malaysia, competitive pressure, complexity, costs associated were found to be significant predictors of the intention to adopt blockchain (Wong *et al.*, 2019).

Blockchain in the supply chain will bring in tandem the additional benefits as well. These benefits can be sustainability in the supply chain and execution of smart contracts via blockchain (Yadav and Singh, 2020; Dolgui *et al.*, 2019) (Table 3).

4.4 Blockchain in agricultural and food supply chains

Consumers worldwide are becoming increasingly conscious about the quality of food delivered to them, so the agricultural supply chains need to be equally efficient (Bhat and Joudu, 2019; Salah *et al.*, 2019). Blockchain in agriculture could be used to improve food safety, and transaction time and costs (Bermeo-Almeida *et al.*, 2018). For instance, in the USA, blockchain is used for tracing the production, supply chain and delivery system of eggs (Bumblauskas *et al.*, 2019). Various studies propose traceability solutions using blockchain systems to trace food products such as meat, wine, mango and fish (Sunny *et al.*, 2020). Internet of Things and blockchain can be juxtaposed to create systems that can create value chain ensuring transparency and traceability (Borah *et al.*, 2020). A decentralised database using blockchain can be developed to track agricultural produce and facilitate fast payment to farmers (Anjan and Sequeria, 2019). Information and communication technology (ICT) E-agriculture system with a blockchain infrastructure can be used at the local and regional scale, and monitoring could be done with the evaluation tool (Lin *et al.*, 2015). Many enablers lead to the successful implementation of blockchain infrastructure in the supply chain, but as shown by empirical study, most significant out of them is traceability followed by auditability and immutability (Kamble *et al.*, 2019). However, in the Indian context, the

S. No.	Papers' Authors	Description
1	Kamble *et al.* (2018a)	Developing a model of Blockchain integrating theories of technology acceptance model (TAM), technology readiness index (TRI) and the theory of planned behaviour (TPB)
2	Quieroz and Wamba (2019)	Literature Review of Blockchain in Supply chain
3	Wamba *et al.* (2020)	Individual blockchain adoption behaviour in logistics and supply chain field in India and USA
4	Wong *et al.* (2019)	The effects of relative advantage, complexity, upper management support, cost, market dynamics, competitive pressure and regulatory support on blockchain adoption for operations and supply chain management among Small-Medium Enterprises (SMEs) in Malaysia.
5	Dolgui *et al.* (2019)	A model for smart contract design in the SC with multiple logistics service providers
6	Yadav and Singh (2019a, 2019b)	Sustainability in the supply chain with Blockchain

Table 3.
Description of papers related to “blockchain in supply chain “theme

lack of government regulation and lack of trust among stakeholders is considered to be the barriers that may restrict adoption of blockchain in the agricultural supply chain (Yadav and Singh, 2020) (Table 4).

5. Observed research gap

The frameworks proposed earlier by the authors have been catering to agricultural supply chains to make them more traceable from procurement, processing to distribution, retailing using blockchain technology (Iyengar, 2017). The framework given by Hatiskar and Pai highlights how blockchain can be used in PDS facilitating procurement from farmers, payment to farmers, then the ultimate movement of grains from storage warehouses to customers through TPDS (Hatiskar and Pai, 2018). RFID is gaining attention in the supply

S. No.	Papers'Authors	Description
1	Rajeev Bhat and Ivi Joudu	Efficient agricultural supply chain
2	Lin *et al.* (2015)	ICT E- agriculture
3	Kamble *et al.* (2019)	Enablers in the successful implementation of Blockchain infrastructure un agricultural supply chains
4	Bermeo-Almeida *et al.* (2018)	Systematic literature review of Blockchain in agriculture
5	Borah *et al.* (2020)	“FARMAR “Method proposed for the use of IoT and Blockchain in Supply Chain
6	Yadav and Singh (2020)	Barriers in the adoption of blockchain in the agricultural supply chain in India
7	Salah *et al.* (2019)	Soybean traceability using Blockchain
8	Anjan and Sequeira (2019)	The supply chain of agricultural produce equipped with Blockchain
9	Sunny *et al.* (2020)	Supply chain traceability through blockchain-based traceability for various products
10	Bumblaus *et al.* (2019)	Blockchain in eggs supply chain
11	Xiong *et al.* (2020)	Applications of blockchain technology in food supply chains, agricultural insurance, smart farming, transactions.

Table 4.
Description of papers related to “blockchain in agricultural supply chain” theme

chain context (Biswal *et al.*, 2020). RFID can lead to warehouse efficiency and effective inventory management in the PDS (Biswal *et al.*, 2018). Pawar *et al.* (2020) used Value Focussed Thinking method to gauge the opinions of various stakeholders involved in PDS and proposed a blockchain-based prototype involving stakeholders including citizens, procurement centre, retailer and quality control authority (Pawar *et al.*, 2020). Singh *et al.* (2020) presented a blockchain-based solution that uses smart contracts and consortium-based ecosystem in PDS (Singh *et al.*, 2020). This paper proposes a conceptual framework that focuses on later stages of the food supply chain of PDS from warehouses to FPS and then to the ultimate beneficiary using blockchain technology and RFID. The later section of the supply chain is being focussed upon as rampant leakages and diversion of supplies take place in these stages only (Sharma and Gupta, 2017; Dreze *et al.*, 2017). The juxtaposition of blockchain and RFID can lead to minimum leakages, higher accountability, transparency and reduced corruption. The paper proposes the framework from managerial and administrational perspective, not IT perspective, to curb the corruption and leakages plaguing PDS supply chain.

6. Research methodology

The paper begins with identification of the problems associated with Indian Public Distribution System. A detailed analysis of the problems has been carried out to gauge the reasons behind the problems. Thorough Literature review has been carried to understand the research perspective of the problems identified (Figure 1). Only papers published in peer-reviewed journals and reports published by Government and established organizations have been considered. Figure 1 explains the criteria of accessing, evaluation, inclusion and selection of the articles. A framework has been developed to connect all the required stakeholders on the blockchain network. The framework would entail certain enablers and disablers which will facilitate its implementation. The enablers and disablers have been discussed in detail in further sections.

7. Proposed framework

Based on extensive literature review and observed research gaps, a blockchain framework has been proposed to connect Ministry of Food and PDS , FCI, central, state and leased warehouses, FPSs throughout India and the beneficiaries. The permissioned blockchain system, where consensus is controlled by participants and read permission is with participants only will be appropriate (Deloitte ASSOCHAM India, 2017). The consensus protocol refers to the method of verifying the legitimacy of the block of transactions. Consensus protocol of Proof of Authority could be used where the authority to verify the blocks will be with specified participants such as FCI, Ministry, warehouses and registered FPSs (Ernst and Young, 2019; Saurabh and Dey, 2020).

The Department of PDS on behalf of the Ministry of Food and PDS forms the blockchain's genesis block. It will have a department to handle the blockchain work of the PDS. The FCI will be another block. The data (biometric information of fingerprints) from Unique Identification Authority of India (UIDAI) needs to be stored in decentralised servers so that it can be accessed by the parties who need it. The biometric information of targeted legitimate beneficiaries, warehouse owners and authorised officers, FPS owners and authorised officers, Ministry and FCI officials handling the system, should be stored in the blockchain system's decentralised servers. All the states, central or hired warehouses of respective states are connected to the blocks of Ministry, FCI and the FPSs of their respective states. The framework also proposes RFID tags to be attached to the grain bags that will enable tracking the movement of goods in transit and in the warehouses (Biswal *et al.*, 2018). RFID tags can

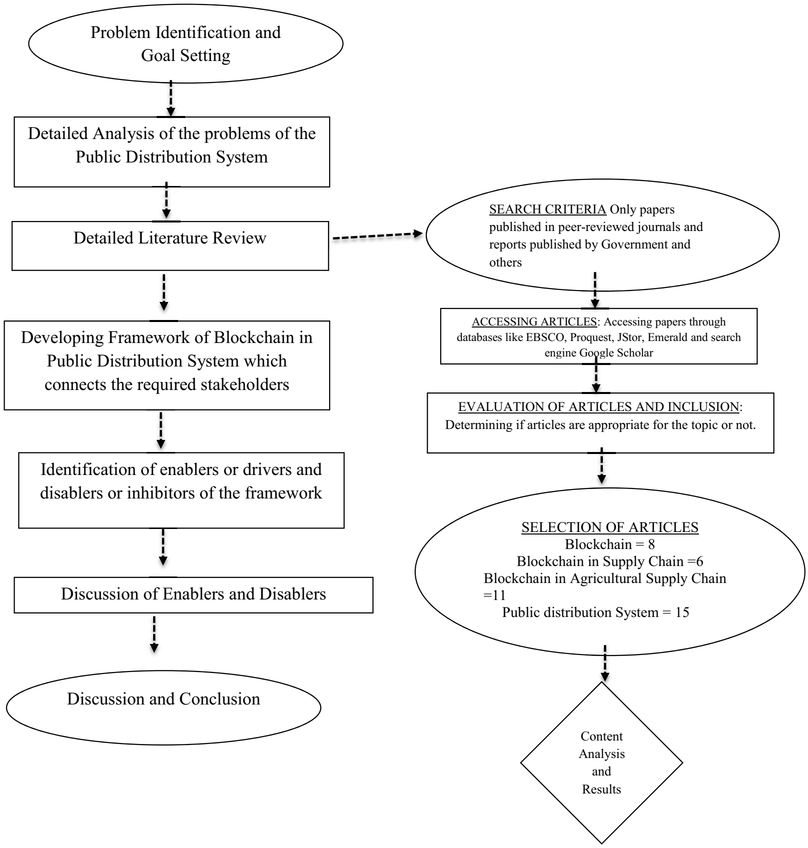

Figure 1.
Diagram depicting the research methodology and literature review process

identify multiple objects simultaneously using radio waves, therefore eliminating the cumbersome process of manual counting

As depicted in the diagram the required information from the Ministry of Food and PDS , FCI and UIDAI will be stored in decentralised servers which could be accessed by FPSs and Warehouses. For example, the biometrics of warehouse managers, FPS owners and the targeted consumers will be stored in servers and information will be provided by UIDAI. Similarly, whatever information is needed by FCI or Ministry about any of the FPS or warehouse can be retrieved from the servers.

7.1 Blockchain Scenario 1

The warehouses (Central/State) attach RFID tags to the grain bags received (Figure 3). The warehouse records all the RFID tags information in blocks and secures it with a hash, which could be the warehouse manager's digital signature (fingerprint). This block is broadcasted to all the blocks (nodes), which would be FCI, Ministry, who will then validate it. After validation, the block of the warehouse joins the blockchain. FPSs raise their demands through FCI apps installed with them. This demand reaches to the nearest warehouse, which has to be satiated by that warehouse. The app would ensure that the demand raised is recorded electronically for tallying later (in case of any discrepancy) and will also connect FPS with the nearest warehouse. The supply of grains from the nearest warehouse will ensure that minimum logistics cost of transportation of bags is incurred. Warehouse supplies the required bags after recording specific RFID tags (attached to those bags) and noting in which PDS shop they are sent (Figure 2).

7.2 Blockchain scenario 2

As soon as the bags reach the FPS, RFID tags are being rechecked and the data is uploaded in the block of that PDS shop secured by the owner's hash (digital signature) (Figure 4). This block (block of the respective FPS) is broadcasted to nodes (FCI, Ministry, Warehouses). The block of this PDS shop will join the blockchain only when validated by FCI, Ministry and the respective warehouse which sent it. The respective warehouse will

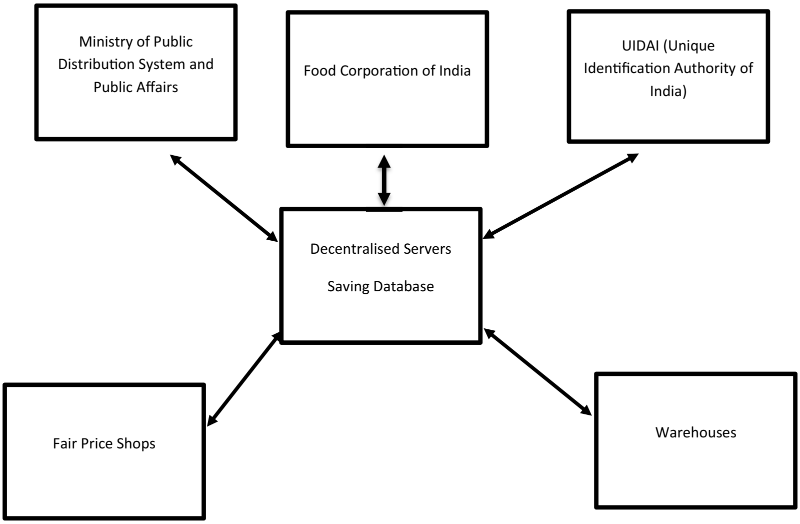

Figure 2. Data from all blocks getting stored in decentralised servers

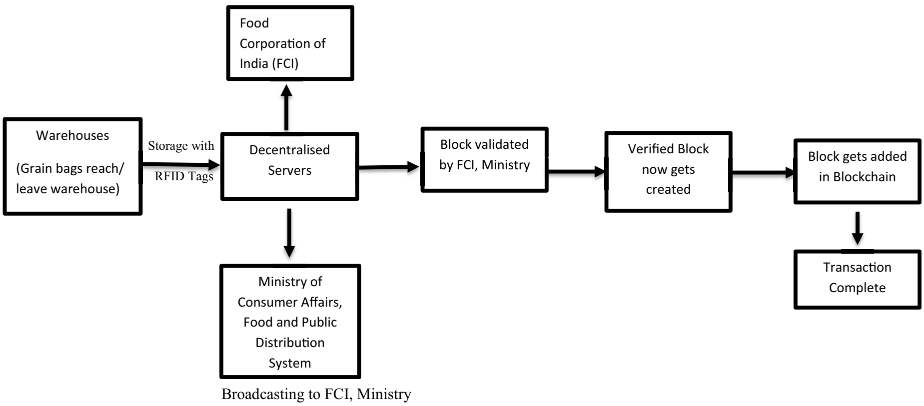

Figure 3. Blockchain scenario 1 depicting the arrival and departure of grains from warehouses

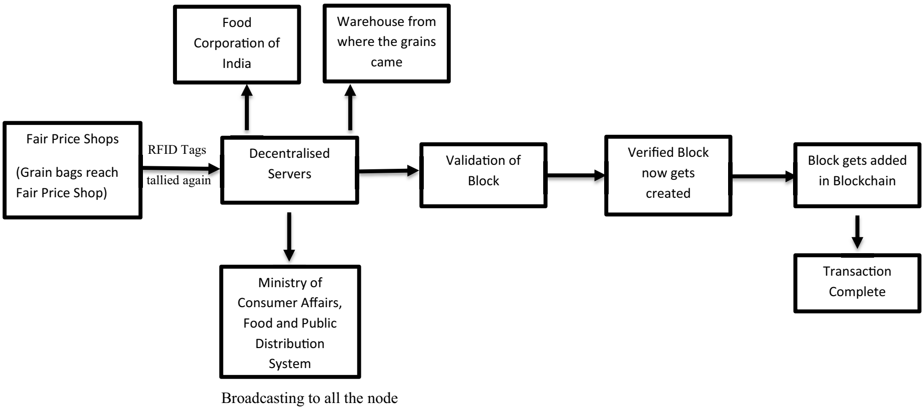

Figure 4.
Blockchain scenario 3 depicting the arrival of grains at Fair Price Shops

tally that RFID tags that left the warehouse have reached destined FPS. After the verification, validation will be sent from the warehouse. Now the block, which is validated by all the authorities, can join the blockchain. Bags are ready to be sold to the general public.

7.3 Blockchain scenario 3

Whenever the goods have to be sold to the consumer, the biometric(fingerprint) is used. The biometric data will ensure no individual buy grains more than once, thus reducing the possibility of any bogus ration card. Biometric authentication can be done via PoS machines which are installed in FPSs under ABBA scheme (Dreze *et al.*, 2017). The consumer will first be verified with his fingerprint whether he is a targeted legitimate beneficiary. If the data of consumer is verified, he can proceed to purchase grains. The consumer will receive grains and can get them weighed on weighing scale in FPS (Figure 5). The consumer needs to close his transaction in the blockchain system. Biometric (fingerprint) of the consumer will close the consumer's block. The block (of the consumer) will join the blockchain only when validated by nodes of FCI, Ministry and PDS shop from where the consumer is buying.

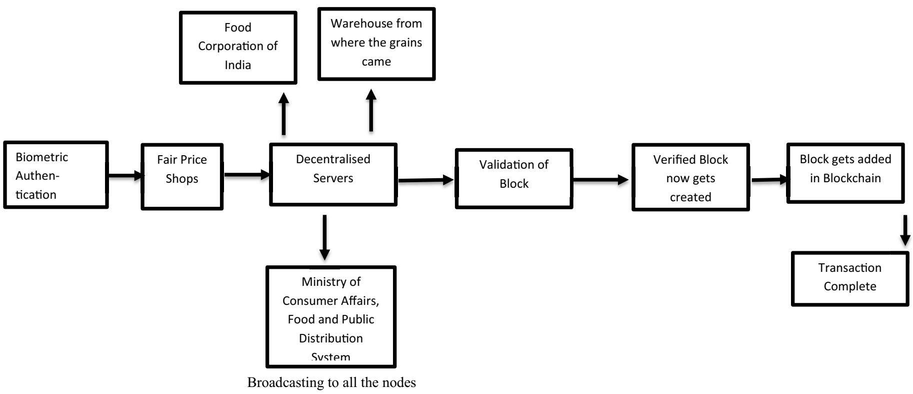

Figure 5.
Blockchain scenario 3 depicting the purchase of grains by ultimate beneficiaries

In case discrepancies arise, FCI, on their end, can do real-time tallying of the two sets of data – demand raised by individual FPS via the app and the consumer hash received in that PDS shop to ensure that the grains reach to the targeted consumers.

8. Identification of the enablers and disablers

Enablers and disablers to the framework have been identified in the subsequent sections. Enablers are the blockchain features that will serve as the facilitators for the framework to fulfil its objective. Disablers will be the detriments associated with the framework that might hold back the framework's functioning. In subsequent sections, enablers and disablers are identified and explained.

8.1 Enablers

8.1.1 Transparency. The first enabler is transparency which would ensure that records cannot be manipulated in blockchain-enabled PDS. Transparency has been identified as the enabler for blockchain technology adoption in the previous literature (Kamble *et al.*, 2018, 2018a, 2018b; Hughes *et al.*, 2019; Wamba *et al.*, 2019, 2020).

The main issue of data visibility is tackled with the help of blockchain (Awwad *et al.*, 2018; Ølnes *et al.*, 2017; Francisco and Swanson, 2018). The biggest benefit is that the check is put at every stage – from warehouses to the consumer. There are three types of fraud that ultimately lead to corruption in PDS – identity fraud, quantity fraud and eligibility fraud. Identity fraud happens when the ration card is issued in the name of the person who does not exist (bogus ration card). This type of corruption will come to the minimum level with blockchain put in the place where ABBA and verification will ensure that there are no identity frauds happening. Eligibility fraud will be catered with only legitimate beneficiary getting the grains, as only those people will get the ration whose data is saved on database (Dreze *et al.*, 2017) Quantity fraud (which generally happens in the form of "katauti") will also get reduced as the beneficiary will have the power not to close the transaction via digital hash (fingerprint) which closes the block and completes the transaction if they do not get allocated grains.

8.1.2 Increased accountability. The inclusion of all the stakeholders and parties in blockchain will make all the parties – warehouse managers, FPS owners accountable where they will be quickly nabbed if they indulge in corruption. Auditability has been identified as the enabler for blockchain technology adoption in the previous literature (Iansiti and Lakhani, 2017; Tapscott and Tapscott, 2017; Kamble *et al.*, 2018, Zyskind *et al.*, 2015; Ølnes *et al.*, 2017).

8.1.3 Immutability. Data entered cannot be imitated by other parties as the digital signature will secure it in the blockchain. Immutability has been identified as the enabler for blockchain technology adoption in the previous literature (Kamble *et al.*, 2018; Wamba *et al.*, 2019)

8.1.4 Traceability. The whole supply chain could be traced from beginning to the end as data is entered, stored and verified at every stage. Traceability further reinforces the accountability where the person identified with a specific scrupulous transaction can be identified in real-time (Kammath, 2018). Traceability has also been identified as an enabler for blockchain technology adoption in the previous literature (Dolgui *et al.*, 2019; Borah *et al.*, 2020; Bermeo-Almeida *et al.*, 2018; Kamble *et al.*, 2018)

8.1.5 Decentralised database of Below Poverty Line families. The decentralised and secured database has been identified as the enablers for blockchain technology adoption in the previous literature (Casino *et al.*, 2019; Huumo *et al.*, 2016). With 58% subsidised food not reaching the target consumers of BPL families, the database created because of blockchain will help solve the crisis.

8.1.6 Logistics cost reduction. Reduced transaction costs have been identified as the enabler for blockchain technology adoption in the previous literature (Huumo *et al.*, 2016; Hughes *et al.*, 2019; Ølnes *et al.*, 2017). The satiation of demand of FPS from the nearest warehouse will reduce the logistic cost in the form of transportation costs, fuel charges and toll taxes involved.

8.2 Other associated benefits

8.2.1 Vigilance from upper authorities. The blocks of Ministry, FCI will keep a vigilant check on the warehouses and FPS owners and will be easily able to trace them and produce records and evidence, in real-time, if they indulge in any sort of malpractices.

8.2.2 Closing of transaction by the consumer. The transaction or the block will be closed by the consumer's fingerprint (digital signature or hash), leading to two benefits. Firstly, once the block closed will be unalterable except when the consumer uses the fingerprint. Secondly , giving power to the consumer to close the transaction will ensure that grains reach consumers. The consumers would do the digital signature or the hash only when they have received the grains, that too the exact quantity, thus reducing the quantity fraud of grains.

8.2.3 Raising of demand by fair price shop through mobile app. FPS raising their demands through the app will ensure that the amount received by that particular shop, will be recorded online. This online recorded quantity would later be audited to gauge that whatever demand is being raised by the shop, has been transferred to consumers, not diverted in the open market by sale.

8.2.4 Digitised ration card and Public Distribution System portability. Ration card will be digitised, thus ensuring all data is recorded online. PDS Portability will become the biggest advantage as the whole data will be saved on decentralised servers; thus, access to all states will be available. Even with IT intervention, the government faced the problem of portability of data of beneficiary from one FPS to another (Sharma and Gupta, 2017).

8.2.5 Integration of data. The government has been envisaging digitisation at all levels of PDS (Economic Survey,2018/2019). However, only digitisation will not serve the purpose. What is required is the integration of that data at all levels so that data could be easily traced whenever needed, in the real-time. This could be easily facilitated by blockchain.

8.2.6 Radio Frequency Identification tags. RFID tags will help count the bags and thus reduce the time to scan the bags (unlike in barcode scanner) and put data in the blockchain. RFID tags can help to trace the asset movement provided that more investment in the infrastructure is being made (Biswal *et al.*, 2020, 2018)

8.3 Disablers

8.3.1 Lack of infrastructure for digitisation. As per the Economic survey (2018/2019), digitisation of ration cards has been achieved in all the states. However, the main component of digitisation involves the basic infrastructure that is internet connectivity. ABBA was started in PDS. It is done through "Point of Sale" (PoS) machine installed at every FPS and connected to the internet where consumers' fingerprints are verified before giving them ration. Internet connectivity is poor in rural areas (Dreze *et al.*, 2017). Internet connectivity would be needed in biometric authentication in the blockchain framework as well.

World Bank data shows that internet penetration is one of the lowest in India, estimating it to be around 27%. Currently, over 55,000 villages remain deprived of mobile connectivity. This is mainly because providing mobile connectivity in such locations is not commercially viable for service providers (Deloitte ASSOCHAM, 2016; PWC ASSOCHAM, 2017).

8.3.2 Lack of trust and government support. Though blockchain is considered to be the platform that can redress trust issues that arise among stakeholders, lack of trust among agro-stakeholders and lack of government regulations were considered as the main barriers that might arise in the agricultural supply chain (Yadav and Singh, 2020).

8.3.3 Lack of skills. Blockchain will require technological expertise, not just to create but to operate as well. PDS dealers have been apprehensive about the PoS system (Dreze *et al.*, 2017). So acceptance of this Industry 4.0 technology will be difficult. There is a shortage of skilled resources with blockchain expertise. Globally, only 45,000–60,000 human resources are skilled in blockchain (NASSCOM Avasant, 2019).

8.3.4 Lack of awareness. Reports suggest that, as recently as 2014, nearly 70% of Indian consumers indicated that lack of awareness was the main reason for not using internet services (Deloitte ASSOCHAM, 2016). The adoption of blockchain technology in such a scenario becomes more difficult.

8.3.5 Discomfort. Difficulty in understanding the application of the technology and perception of the people that blockchain technology is a complex technology can be referred to as discomfort. Complicated blockchain design and resistance by agro-stakeholders can prove detrimental for blockchain implementation (Yadav and Singh, 2020).

9. Results and practical implications

The proposed framework of Blockchain in PDS can guide Ministry of Food and PDS (Central Government), FCI and state governments which manage the PDS in India at the policy level. The framework will ensure transparency in transactions carried out the transactions recorded cannot tamper as they are immutable and can be carried out by the person authorised only, as the blocks are secured with person's digital hash (fingerprint). If the person indulges in malpractice, the person will be directly accountable and cannot parry away from responsibility as the transaction would be added only after his/her authorisation (digital hash – signature). RFID tag would contain the details where the goods are procured from, the product's weight at the time of packaging, time and date of packaging and any other specification needed (Saurabh and Dey, 2020). RFID tags attached to the bag will ensure that the bag is not tampered or diverted in transit. As bags leave the warehouse, their RFID tags are recorded and secured in the block. The same RFID should reach to decided FPS (with the same RFID Tags). It is after tallying of these RFID tags the block of FPS will close (thus ensuring RFID tags have not tampered in transit). The consumer will receive the grains with biometric authentication to ensure that they are the genuine beneficiary. On receiving grains from FPS, consumers will then do a digital signature(hash) with their biometric to close their specific block. This liberty of letting consumers close their block will ensure that the consumer receives grains. If any discrepancy is noted, the consumer will not close the block and can complain to higher authorities. Higher authorities on checking blockchain transactions will find this specific consumer's block unclosed or unadded and can further inquire.

Tables 5 and 6 give further insight into the implementation process of framework considering enablers and disablers. These tables also give a brief description of enablers and disablers and distinguish them on the basis whether they are internal to framework or external to the framework. Internal to framework means enabler or disabler inherent in blockchain's nature, external to framework means the aspect beyond the control of the blockchain. Tables 5 and 6 also elaborate about affected stakeholders of this supply chain, who will benefit from the enabler and face problem/discomfort because of disabler.

Figure 6 gives a comprehensive summary of the framework, how blockchain will enable transactions, track the movement of goods and ensure that the goods reach the targeted beneficiaries.

Table 5.
Description of enablers along with affected stakeholder and relationship with the framework

S.No.	Enablers	Description	Internal/external to Framework	Affected Stakeholder	Reference
E1	Anonymity and Privacy	The privacy-preserving framework that allows more information security	Internal	Beneficiaries, Warehouse Managers and FPS owners	Hughes *et al.* (2019), Ølnes *et al.* (2017)
E2	Auditability	Auditable, trust-free, tamper- proof	Internal	Government, Beneficiaries	Iansiti and Lakhani (2017), Tapscott and Tapscott (2017)
E3	Decentralised database	Data saved on various servers, not on a single computer.	Internal	Government, Beneficiaries	Casino *et al.* (2019), Huumo *et al.* (2016)
E4	Immutability	Inability to change, audit trail.	Internal	Government, Beneficiaries	Kamble *et al.* (2018), Wamba *et al.* (2019)
E5	Secured database	Asymmetrical cryptography and exchange validation	Internal	Government, Beneficiaries Warehouse Managers and FPS owners	Hughes *et al.* (2019), Ølnes *et al.* (2017)
E6	Shared database	Stored in ledgers shared between parties	Internal	Government	Hughes *et al.* (2019), Kamble *et al.* (2018a, 2018b)
E7	Traceability	Real-time audit trail and inspection	Internal	Government, Beneficiaries	Dolgui *et al.* (2019), Borah *et al.* (2020)
E8	Transparency	Data can be traced back to each block.	Internal	Government, Beneficiaries	Kamble *et al.*, 2018, Kamble *et al.*, 2018a, 2018b
E9	Reduced transaction cost	Decentralised database, no need for intermediaries and cryptographic signature protection reduces transaction cost.	Internal	Government, Warehouse Managers and FPS owners	Hughes *et al.*, 2019, Kamble *et al.* (2018a, 2018b)

S.No.	Disablers	Description	Internal/external to Framework	Affected Stakeholder	Reference
D1.	Discomfort in usage	Difficulty in the usage of Blockchain Technology	Internal	Beneficiaries Warehouse Managers and FPS owners	Yadav and Singh (2020)
D2	Lack of infrastructure	Lack of internet facilities	External	Government, Beneficiaries Warehouse Managers and FPS owners	Deloitte ASSOCHAM (2016), PWC ASSOCHAM (2017)
D3	Lack of skills	Lack of technical skills for designing, maintaining and handling	External	Government, Warehouse Managers and FPS owners	NASSCOM Avasant (2019)
D4	Low level of awareness	Digital illiteracy	External	Beneficiaries Warehouse Managers and FPS owners	Deloitte ASSOCHAM (2016)
D5	Lack of trust	Lack of trust among agricultural stakeholders	Internal	Beneficiaries, Warehouse Managers and FPS owners	Yadav and Singh (2020)

Table 6. Description of disablers along with affected stakeholder and relationship with the framework

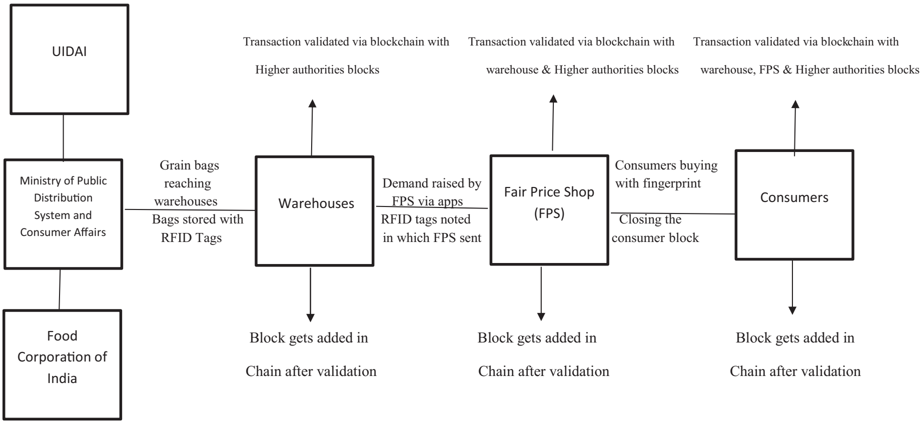

Figure 6.
Comprehensive summary of proposed framework

The total value of corruption in the system is estimated to be around Rs 3.58 bn (INR) per year (Transparency International India, 2005; Gupta and Misra, 2018). A private (permissioned) blockchain model opted, which can process 0.5 million transactions daily will cost around Rs 23 bn (INR) 23m in year 1, and cost will subsequently reduce with every passing year. This estimated cost includes onboarding costs (initial build, software implementation and hardware costs), cloud costs (storage capacity and transaction storage depending on the number of transactions), ongoing maintenance costs and monitoring costs (quality review and network assessment costs) (Ernst and Young, 2019). These costs include the remuneration of blockchain experts and IT experts, who will be involved in handling mechanism depending on transactions, increasing as the number of transactions increases. Single 96 bit RFID tag which could store food supply chain data (Saurabh and Dey, 2020), is available at Rs 10 (INR) at retail price, which if procured at wholesale price or produced at government level would cost even less. Even if the transactions increase manifolds, the cost incurred would be less than the amount lost to corruption. Moreover, blockchain usage will ensure that the grains are reaching the targeted beneficiaries, thus fulfilling the objective.

10. Conclusion

India is home to 194.6 million undernourished people, the highest in the world, according to the recent annual report by the Food and Agriculture Organisation of the United Nations. According to the World Health Organisation (WHO), close to 1.3 million children die every year in India because of malnutrition (WHO) (Lal, 2015). Blockchain can serve as the solution for these problems provided that the big leakages are being encountered in the PDS . The framework can ensure transparency, accountability, traceability, integrated, secured and shared database. The enablers and disablers need to be analysed in tandem with the framework to ensure the framework's effective implementation. However, the lack of digital infrastructure would serve as a hurdle. Robust internet connectivity is required in rural areas to harness blockchain's power as the internet less blockchain technology would take time to develop.

11. Limitations and future research

The framework is based on certain assumptions for its application. There should be robust internet connectivity, adequate availability of infrastructure and technical expertise to enable blockchain usage. Adequate training needs to be provided to warehouse officers and FPS owners to use the blockchain system. Even after implementing the framework, there are chances that the corrupt officials can replace the grains with sub-standard grains, without affecting RFID tags attached to bags.

The framework is based only from the level of the warehouse to consumers. Future research can design framework including farmers and other intermediaries. This will enable tracking from where the grains are procured and testifying the quality of grains (Bhat and Joudu, 2019). Future research can investigate the views of stakeholders involved in PDS and whether they will accept such a framework if implemented. The current internet connectivity is poor. National Optical Fibre Network that envisaged to provide internet facilities to the rural areas, 67% of them were found to be non-functional at the pilot stage (PWC ASSOCHAM, 2017). The lack of electricity adds fuel to the fire in the problem of lack of infrastructure. The disablers of the framework will further act as the limitations to the framework.

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Corresponding author

Himani Mishra can be contacted at: himani_phdmf19@iift.edu