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Digital integration to enhance market efficiency and inclusion of smallholder farmers: a proposed model for fresh fruit and vegetable supply chain

REVIEW ARTICLE

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Abstract

High-value agriculture in India is witnessing a transformation, specifically in fresh fruits and vegetables (FFV). Supply chain stakeholders, mainly small and marginal farmers, receive a very minimal share in consumer rupee due to market uncertainty, high post-harvest losses, information asymmetry, lack of processing facilities and the erratic demand-supply situation. The current study draws from an extensive review to propose a competitive, inclusive, sustainable and scalable supply chain model of primary processing centers connecting farmers directly and efficiently with consumers. The proposed model will connect producers with the rest of the supply chain and streamline the supply chain process to reduce post-harvest losses as much as possible. The integration of a market information system will ensure transparency to help in better decision-making, reduced intermediaries and information asymmetry for producers, as well as the systematic disposal of the produce. The model will increase the efficiency of the FFV supply chain and has practical implications for agribusiness management and policymakers in relation to FFV supply chain development in India.

Keywords: supply chain, fresh fruits and vegetables, primary processing centers, market information system, India
JEL code: Q1

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1. Introduction

The agriculture sector in the developing world, especially in southern and south-eastern Asia including India, is undergoing a silent transformation characterized by rapid diversification towards high-value agricultural produce that includes fruits, vegetables, meat, eggs, milk, and fish. Such a transformation has a profound effect on the nature of agricultural supply channels, opportunities for smallholder farmers, and public and private investments (Gulati, 2016). Growth in high-value agriculture implies a greater need for linkages between farmers, processors, traders, and retailers to coordinate supply and demand. This transformation presents an opportunity to raise farmers' income by effectively managing market risks. Managing production risks and market participation can be a challenge for smallholder farmers; linking farmers and buyers can overcome these obstacles (Devaux *et al.*, 2016). In the developing countries of Asia, growth in the agricultural sector has been increasingly driven by a growing demand for high-value products (Reardon and Timmer, 2014; World Bank, 2007).

India, too, has seen a major shift towards the production of high-value crops over the past three decades. In 2013-2014, the average area under fruits and vegetables more than tripled to 16.2 million ha, representing a compound annual growth rate of 3.9%. The production of fruits and vegetables increased at a compound annual growth rate of 4.8% over the past two decades to an average of 243.7 million metric ton (GoI, 2017b). Fruits and vegetables account for nearly 90% of the total horticultural produce in India. Small and marginal farmers contributed around 70% to the total production of vegetables and 55% to fruits, with a 44% share of land area (Mahendra Dev, 2014). According to the national horticulture board's database, India produced a record high of 305.4 million tons of fruits and vegetables in 2017-2018 (GoI, 2017a). The consumption pattern of Indian consumers is changing: fruits and vegetables are increasingly being consumed instead of cereals and pulses (Nandi, 2018). This spurt can be attributed to the structural transformation of demand patterns of high-value products, triggered by rising incomes, urbanization, changes in dietary preferences, and increased awareness of the benefits of consuming fruits and vegetables. The growing demand for high-value products has opened up opportunities for farmers to diversify their production and potentially increase farm incomes. However, in addition to high post-harvest losses (PHL) and poor infrastructure, small and marginal farmers are being excluded from emerging supply chains owing to the high transaction cost of aggregation, poor produce quality, and information asymmetry among the stakeholders (Devakumar and Shankar, 2014; Nandi *et al.*, 2017). Integrating smallholder farmers in the supply chain leads not only to higher prices for producers but also lower prices for consumers. Supply chain integration is a major strategy to guarantee reliable sourcing of fresh fruits and vegetables (FFV) to urban supermarkets in emerging economies. Fresh produce requires high frequency production, consistent delivery, and stable quality. Procurement arrangements between producers and supermarkets are normally based on observable characteristics like volume, size, and color (Nandi *et al.*, 2017). Given the sheer size of the market and premium price, the emergence of organized retailing presents potentially profitable market opportunities for smallholder farmers who can supply regularly and as per consumer standards. But the smallholder farmers in India are more attuned to producing within the context of particular seasons and selling to local markets, without targeting production to the requirements of the market. Their philosophy is 'produce first, then look for the market' instead of analyzing the market opportunities, making the necessary contractual arrangements with buyers, and then producing what the market really wants (Nandi *et al.*, 2017).

Furthermore, loss is currently more likely to be the result of poor supply chains because of poor infrastructure. The economic value of the losses in fruits and vegetables including cereals, pulses and oilseeds is approximately INR 92,651 crores[1] (US$ 15 billion) (Gulati, 2016). Fruit and vegetable losses across the supply chain in India are 8-10% at the farm, 5-6% in transit, 2-3% in *Mandi*/warehouse, 12-15% at the store/retail, and around 1% at the customer end (Mehta, 2017). Lack of appropriate, affordable farm machinery, packaging and efficient transport facilities, adequate storage infrastructure and unorganized retailing are important causes of food loss (Gulati, 2016). The hurdles in the supply chain of fruits and vegetables are inefficient marketing

[1] A crore denotes 10,000,000

channels and an inadequate marketing structure that cause high and volatility in prices, leading to a lower share of the consumer rupee reaching the farmer (Negi and Anand, 2015). The presence of intermediaries is pronounced in the marketing channels of fruits and vegetables. The middlemen who control the market do not add much value to the perishables, and the consumers and producers are worse off. Problems of wastage, quality deterioration, and the frequent mismatch between supply and demand (both spatially and over time) are some of the other problems that have been plaguing the fruit and vegetable marketing channel (Naik and Suresh, 2018). Their perishable nature, seasonal production, and bulkiness make the marketing of horticultural crops quite complex. Furthermore, dynamic responses to changing consumer demands and sustainability requirements, maintaining safety and quality standards, and efficient logistics management are the major challenges in building an efficient agri-supply chain in developing economies.

It is therefore of critical importance to develop an efficient and inclusive supply chain model for FFV. To check such inefficiencies in the marketing and supply chain of perishables, it is proposed to incorporate innovations in the existing supply chain model for FFV. These innovations should be directed towards increasing the farmer's share in the consumer rupee in the price for FFV, reducing the length of the supply chain by surpassing intermediaries, increasing per capita availability of fruits and vegetables, reducing PHL, and increasing consumption by reducing the price volatility of the produce.

Given the background, the objective of the study is to study the existing literature on PHL and market efficiencies across the FFV supply chains, and to propose an inclusive, competitive supply chain model for smallholders to access lucrative markets.

The next sections in the paper are organized as follows: Section 2 discusses the conceptual framework of the proposed model and current practices in the marketing of fruits and vegetables in India. Section 3 discusses the literature review related to studies on marketing efficiencies of horticultural crops in India and the estimated PHL to help identify the major constraints in the supply chain for fruits and vegetables. Section 4 discusses a supply chain model with innovations catering to different aspects of the supply chain. The final section identifies the challenges in the current FFV supply chain and how the proposed model can make it more efficient.

2. Conceptual framework

Majority supply chain guides build their conceptual framework around the concepts of chain governance and upgrading (Devaux *et al.*, 2016; Springer-Heinze, 2007; Webber and Labaste, 2009). These guides help design a supply chain development strategy to build an inclusive supply chain and improve relations between producers and other actors in the chain. The conceptual framework for the proposed model is presented in Figure 1. This study focuses on the specific level in the FFV supply chain, and integrating market information system (MIS). The proposed model focuses on increasing the efficiency of the FFV supply chain by setting up primary processing centers (PPCs) by farmer producer organizations[2] (FPOs) with initial support from government funding and creating effective forward and backward linkages for the produce through the PPCs. The rationale of the concept is to: (1) integrate the complete supply chain into an ICT-based platform; (2) maintain transparency in the flow of information across the supply chain and different stakeholders; (3) provide a platform to evaluate produce standards; (4) provide a system for order cycle management and inventory management; and (5) provide ICT interventions for market integration of farmers. The details about each level of the supply chain are explained in Section 5.

[2] FPO, formed by a group of farm producers, mainly small and marginal farmers, is a registered body with producers as shareholders in the organization. It deals with business activities related to the farm produce and works for the benefit of the member producers.

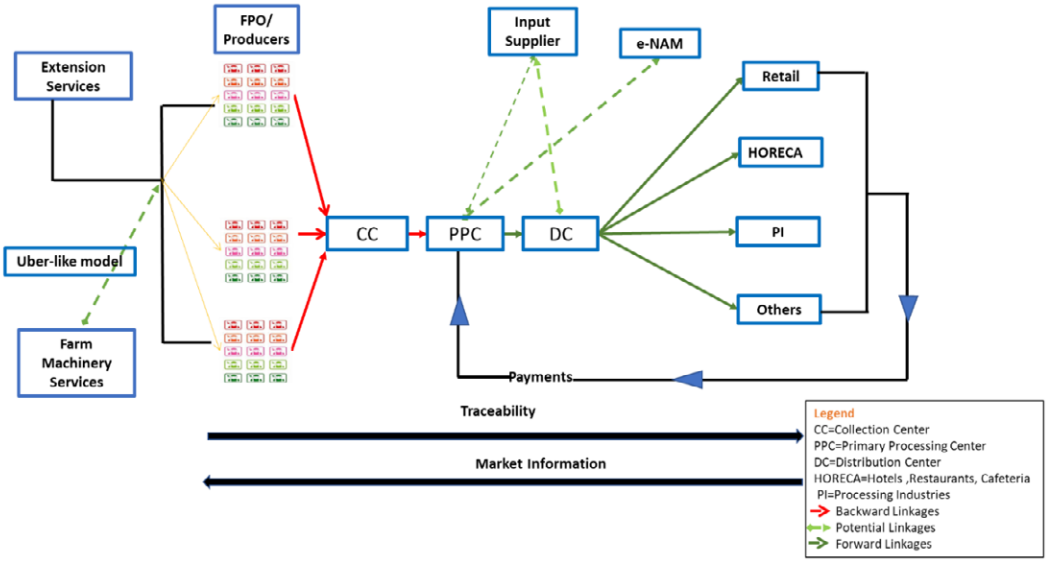

Figure 1. Conceptual framework.

3. Existing practices in the marketing of fruits and vegetables in India

The marketing of horticultural crops is quite complex and risky due to seasonal production, bulkiness, and the perishable nature of the produce. The range of prices from farmers to consumer is an outcome of demand and supply and transactions between the various intermediaries at different levels of the marketing system. The marketing arrangements at different stages also play an important role in price levels at various stages from farm to fork. This is what differentiates the marketing system of fruits and vegetables from that of other agricultural commodities, particularly in providing time, form, and space utilities. Food grains have a better market infrastructure while fruit and vegetable markets are not so well developed and are often congested and unhygienic (Rais and Sheoran, 2015). The supply chain for traditional retailing of fruits and vegetables has a multi-layered marketing channel with inadequate infrastructure and poor linkages that have a bearing on the growth potential of fruit and vegetable crops. These weak linkages bring down the price received by the farmer, which is about a quarter to half the retail price that the consumer pays (Reddy *et al.*, 2010).

There are more than 43,000 periodic markets in India (Velayudhan, 2016). Traditional retailing in fruits and vegetables in India involves *sabzeemandis* (fruit and vegetable markets), specific shops for vegetables and fruits, and roadside vendors selling from handcarts, cycle-carts and baskets (Velayudhan, 2016). Traditional retailing in FFV is characterized by spatial scattering and higher time consumption. The distribution of selected commodities in the traditional market channel involves multiple intermediaries and high cycle times (Reddy *et al.*, 2010). There is considerable wastage of FFV because of inadequate post-harvest handling, lack of cold storage and processing facilities, and inefficient marketing channels. For example, in Andhra Pradesh very few retailers in the traditional retail channels maintain grades and standards in product procurement due to lack of awareness and infrastructure. A comparison of modern and traditional retailing channels for fruits and vegetables conducted in Andhra Pradesh showed that 19.8% of gross value is accrued by farmers in the traditional chain and intermediaries like village merchants, wholesalers, middlemen, and commission agents take the lion's share from the gross value, while in a modern retail chain, farmers received 22.75% of the total gross value and supermarkets received 38% of the total gross value[3] (Reddy *et al.*, 2010). In Haryana, farmers in contract with retail chains were found to receive INR 100-150[4] per quintal more compared to other channels, while the difference in net gain between contract and non-contract farmers was negligible,

[3] Values are based on the average prices received for five major vegetables, namely tomato, cabbage, aubergine, okra, and local bean.
[4] INR 71 = 1 US$ (exchange rate in December 2018)

indicating the difference in increased returns due to increased productivity (Bathla, 2016). Agriculture marketing policies in India are encouraging private players to invest in agribusiness and work directly with farmers through contract farming. For example, a big retailer like BigBasket procures 60% of its FFV directly from farmers through its 20 collection centers (CC) across the country. Direct sourcing has increased company margins by 6-7% and farmer incomes by 10-15% (Jayachandran, 2017). Organized retailers like ABRL's More, Reliance Fresh, ITC Choupal Fresh, Heritage's Fresh and Spencer's procure 25% of the total fruits and vegetables produced in Vantimamidi (a vegetable growing region near Hyderabad, Telangana, India). Small and marginal farmers constitute around 65% of the farming population working with retail chains. Higher prices, use of electronic weighing scales, and no commission charges payable at the *mandi* were the main reasons for farmers wanting to work with organized retailers in Hyderabad (Sulaiman *et al.*, 2011).

3.1 An enabling agribusiness policy environment

Given the Government of India's ambitious plan to double farmers' incomes by 2022, an enabling agribusiness policy environment can bring innovations in agricultural marketing. Linking farmers directly to markets is a high priority so that they can obtain a higher margin in the consumer rupee. Below are some of the initiatives the Government of India has taken to strengthen supply chains and the marketing system in recent years.

- *Electronic national agriculture market*

This is a pan-India electronic trading portal which networks existing APMC *mandis* to create a unified national market for agricultural commodities (National Electronic Agriculture Market, 2016). It helps farmers, traders and buyers to conduct online trading in commodities in the country. The objective is to aid better price discovery and provide facilities for smooth marketing of their produce. eNAM proposes to integrate 585 regulated wholesale markets or APMCs on one electronic platform. This will enable farmers to sell their produce to the highest bidder. The main purpose of eNAM is to ensure transparency in the buying and selling of agri-commodities.

- *Model contract farming act 2018*

India's Ministry of Agriculture and Farmers' Welfare has prepared a 'model contract farming act' for circulation to states for its adoption (GoI, 2018). The act aims to integrate farmers with bulk purchasers such as exporters, agri-businesses, etc., for better price realization through mitigation of market and price risks and for ensuring the smooth supply of raw agri-materials to agri-businesses. One of its important features is to promote FPOs/farmer producer companies to mobilize small and marginal farmers. FPOs play a major role in promoting contract farming and services contracts. The national bank for agriculture and rural development is targeted to promote 5,000 FPOs in the country in the next two years (Bhosle, 2018).

4. Literature review

Many studies have been conducted on FFV supply chains in India focused on various aspects of chain efficiency. A study on the 'need for paradigm shift to improve supply chain management of fruits and vegetables in India' identified the prevalence of a large number of intermediaries in the supply chain; the domination of traders where farmers largely rely on intermediaries are important reasons for chain inefficiency. There are a large number of local agents and commission agents making supply chains inefficient for producers. The study states various strategies, including government agencies taking up the functions of a village level aggregator, and the creation and strengthening of farmer-based organizations in production and marketing. In addition, state government agencies can enter into the higher value addition activities of fruit and vegetable processing (Halder and Pati 2011; Veena *et al.*, 2011). Similarly, another study entitled 'supply chain management and Indian fresh produce supply chain: Opportunities and challenges' highlighted that the main causes of chain inefficiencies include a lack of backward-forward linkages from farmer to customer in the remote areas, linkages between industry, institutions, linkage between farmer and processing unit in the

absence of processing unit and poor linkage in the marketing channel. Contract farming by public-private partnership model and the role of NGOs as intermediary between the farmer and companies are important recommendations from the study to address the abovementioned inefficiencies along the chain (Singh *et al.*, 2009). Several studies have identified that limited or lack of appropriate advanced technologies in food processing and packaging, a lack of storage/warehousing facilities, and poor connecting roads are the reasons for poor performance of existing supply chains. Additional reasons include a lack of knowledge about post-harvest technologies and a lack of awareness and education among farmers about post-harvest management and quality seeds. Rural entrepreneurship development in technology, engineering, food science and the setting up of semi-processing and cold storage units by entrepreneurs near the area of production are some of the suggestions from the studies to address the existing challenges along the fruits and vegetable chains (FICCI, 2010; Halder and Pati, 2011; Narula, 2011; Rathore *et al.*, 2010; Sharma and Singh, 2011; Singh *et al.*, 2009; Veena *et al.*, 2011). Farmer's market information is crucial in obtaining higher prices for their produce. However, the majority of farmers in India have no or limited access to market information related to price, product flow, food processing units, market demand information and intermediaries (Shukla and Jharkharia, 2013; Veena *et al.*, 2011). A study by Veena *et al.* (2011) reported that poor hygiene and safety standards, less control over product safety and quality across the supply chain because of manual handling, and a lack of track-and-trace facilities mean that fresh produce does not comply with international standards. In addition, a lack of transparency in transactions between different stakeholders in the supply chain leads to inefficient price points and high price fluctuations in agricultural produce. Especially as a result of pricing at local *mandi* (market) and dramatic fluctuations in *mandi* prices, farmers are not receiving the right price for their produce in the market even when it comes to seasonal fruits and vegetables. Tables 1-3 presents the evidence from literature reviews on market efficiency, producer's share in the consumer rupee and PHL of select horticultural crops.

Table 1. Summary of literature review on marketing efficiency of horticultural crops in India.

References	Crops/location	Incremental net return in the shortest channel over traditional marketing channel	Marketing efficiency (organized retail over traditional)
Mangala and Chengappa, 2008	*Brassica oleracea var. botrytis* (cauliflower); *Brassica oleracea var. capitate* (cabbage); *Solanum lycopersicum* (tomato); *Daucuscarota* (carrot) – Hoskote/Bengaluru, Karnataka	40, 48, 34, and 18% in cauliflower, cabbage, tomato and carrot, respectively	–
Dastagiri, 2010	*Solanum tuberosum* (potato); *Solanum lycopersicum* (tomato) – Bengaluru, Karnataka	–	0.75 and 0.73 in potato and tomato chains, respectively
Swaminathan *et al.*, 2013	*Abelmoschusesculentus* (okra), *Solanum tuberosum* (potato), *Allium cepa* (onion) – Coimbatore, Tamil Nadu	–	2.07 and 3.33 in okra and potato, respectively
Dastagiri, 2010	*Musa* (banana)	–	1.05
Suresh and Murthy, 2012	*Vitisvinifera* (grapes) – Coimbatore, Tamil Nadu	2.97%	–

Table 2. Summary of literature review on producer's share in consumer rupee in horticultural crops in India.

References	Crops	Location	Producer's share in consumer rupee (%)
Dastagiri, 2010	*Solanum melongena* (brinjal), *Manihot esculenta (*cassava), *Cucumisanguria* (gherkin), *Solanum tuberosum (*potato)	Tamil Nadu	75
Swaminathan *et al.*, 2014	*Solanum lycopersicum* (tomato)	Tamil Nadu	55
Swaminathan *et al.*, 2013	*Abelmoschus esculentus* (okra), *Solanum tuberosum* (potato), *Allium cepa* (onion)	Coimbatore, Tamil Nadu	60
Madhumitha, 2015	*Daucus carrota* (carrot), *Solanum tuberosum* (potato)	Udhagamandalam, Tamil Nadu	59-89 and 74-90, respectively
Umagowri and Chandrasekaran, 2011	*Musa* (banana)	Coimbatore, Tamil Nadu	47-63
Kumaresh and Sekar, 2013	*Magnifera indica* (mango) var. Bangalora, Alphonso and Neelum	Krishnagiri, Tamil Nadu	76.43, 86, and 75.42, respectively

Table 3. Summary of literature review on post-harvest losses (PHL) in fruits and vegetables in India.

References	Crops	Location	PHL (%)
Murthy *et al.,* 2009; Gajanana *et al.*, 2008	*Mangifera indica* (mango), *Vitis vinifera* (grapes), *Punica granatum* (pomegranate), *Carica papaya* (papaya) and *Musa* (banana)	Andhra Pradesh and Tamil Nadu	15, 14, 15, 25 and 14, respectively
Sab *et al.*, 2017	*Mangifera indica* (mango)	North Karnataka	34
Nanda *et al.*, 2012	*Psidium guajava* (guava), *Manilkara zapota* (sapota) and *Carica papaya* (papaya)	all India	18, 6 and 7, respectively
Kitinoja and Kader, 2015	*Allium cepa* (onion)	Karnataka and Tamil Nadu	27

Among the various methods for estimating marketing efficiency, the majority of the studies discussed in Table 1 have used Acharya's approach (Sanjiv, 2014) that takes into account total marketing cost (MC), net marketing margin (MM), the price received by the farmers (FP), and the price paid by the consumer (RP):

$$\text{Marketing efficiency (ME)} = FP / (MC + MM) \quad (1)$$

Shepherd's formula (Sanjiv, 2014) is another common approach that has been used in the studies:

$$ESC = [(V / I) - 1] \quad (2)$$

Where ESC is index of efficiency of supply chain, V is the value of goods sold, and I is the total marketing cost. The studies on marketing efficiency of horticultural crops are limited. Majority of them have been on potatoes, tomatoes, onions, and carrots. There are a few studies on cabbage, cauliflower and okra. The producers' share in the consumer's rupee is calculated using the formula:

$$PS = (PF / PR) \times 100 \quad (3)$$

Where PF is price received by the farmer and PR is the retail price/consumer price. The producer's share in the consumer's rupee varies between 40 and 61% on average for vegetables and between 60 and 90% for potatoes in particular. For fruits, on average, it ranged between 41 and 68% in the southern state of Tamil Nadu and between 56 and 82% in the eastern state of West Bengal.

The marketing cost of vegetables was found to be lower in Andhra Pradesh (7-24%) and West Bengal (5-23%) compared to Manipur (5-60%) and Rajasthan (16-22%) due to a greater number of market intermediaries. Tamil Nadu (4-9%) and Punjab (6-7%) had the lowest marketing costs because of direct marketing. Marketing efficiency for vegetables, calculated using Acharya's modified method, was also found to be highest in Tamil Nadu and Punjab compared to Andhra Pradesh, Karnataka, Manipur, West Bengal, and Rajasthan because of direct producer-consumer linkages in the Tamil Nadu and Punjab states. Factors like marketing costs, marketing margin, transport costs, and labor charges most negatively affected marketing efficiency in the vegetable supply chain in Tamil Nadu, Andhra Pradesh, Rajasthan, West Bengal, Punjab, and Manipur (Dastagiri *et al.*, 2013).

The majority of the fruit and vegetable value chains had significantly higher returns in organized retail. The producers' share in the consumer's rupee was higher for vegetables compared to fruits. Given that the major fruit and vegetable markets are concentrated in the southern states of Karnataka, Andhra Pradesh, and Tamil Nadu, as well as the major marketing innovations (SAFAL markets of Karnataka, Rythu Bazaars in Andhra Pradesh, farmer's markets in Tamil Nadu, contract farming dominating the southern states), a large number of studies on the supply chains focused on this region (Table 2 and 3). Northeast India is least represented in these studies due to the lack of marketing cooperatives, high transportation costs, lack of proper transportation, the domination of private traders, and frequent price fluctuations. Lack of proper market infrastructure and storage facilities inhibit the growth of proper markets and formal supply chains in FFV, while there is great scope for development with low initial investment and high-income potential (Deka and Sarmah, 2012).

PHL cause about 30% wastage of produce, and farmers' realizable value is lost as commission; supply chain mishandling and losses in price take up about 14-58% (Narula, 2011; Veena *et al.*, 2011). Lack of packaging and storage facilities, improper handling of produce, lack of linkage between farmers and processing units, lack of linkage in marketing channels, and a large number of intermediaries are critical factors that lead to PHL in fruits and vegetables in India (Gardas *et al.*, 2017, 2018). A content analysis of studies on PHL and wastage in the supply chain in India identified poor or lack of storage infrastructure, a large number of intermediaries, lack of awareness and knowledge among farmers about post-harvest handling of FFV, rough handling and improper storage, and inadequate transportation facilities as major contributing factors (Negi and Anand, 2016). PHL of up to 40% have been reported in grapes and tomato, while bottle gourd recorded about 5% loss. On an aggregate level, the tomato was found to be most prone to PHL, while on-farm losses were highest for vegetables owing to lack of knowledge about post-harvest management (Sharma and Singh, 2011). The shelf life of fruits and vegetables and chances of storage loss are highly dependent on their type and water content. Under ideal weather conditions, only 3-5% storage loss is expected in onions which comprise about 85% water; losses sharply increase to 25-30% with an increase in temperature (Biswas, 2017). Details of some of the total harvest and PHL in major fruits and vegetables at the national level are provided in Table 4.

High moisture content (70-95%), soft texture, and high respiration and transpiration rates make fruits and vegetables highly perishable and susceptible to PHL. In addition, inadequate post-harvest management increases losses at different stages from harvesting to consumption (Mitrannavar, 2012). Since losses at the farm level are higher than losses during storage, this opens up opportunities to incorporate supply chain models that not only enhance the farmer's productivity but also help in managing harvest and post-harvest operations, thereby resulting in a decline in losses. In mangoes, PHL at different stages from harvesting to consumption were quantified: losses at the farm level (8.44%) were highest compared to those in the wholesale market (4.93%), retail market (5.46%), storage (5.65%), processing units (3.19%), and at the

Table 4. Harvest and post-harvest losses (%) in some fruits and vegetables in India (IIHR, 2013).

Crop	The total loss in farm operations	The total loss in storage	Overall total loss
Apple	11.06	1.20	12.26
Banana	4.18	2.42	6.60
Mango	10.64	2.11	12.75
Grapes	6.57	1.73	8.3
Guava	13.92	4.13	18.05
Papaya	5.06	2.28	7.34
Cabbage	4.61	2.33	6.94
Cauliflower	4.85	2.03	6.88
Potato	6.73	2.26	8.99
Onion	5.17	2.34	7.51
Tomato	9.94	3.04	12.98

consumer level (6.82%) (Sab *et al.*, 2017). State-wide losses in major fruit and vegetable producing states in India are as mentioned in Table 5.

The purpose of the literature review was to identify the major bottlenecks in the supply chain of fruits and vegetables requiring interventions. Below are the main challenges that have emerged from the literature review:

- Faulty on-farm harvesting and handling practices lead to enormous losses in FFV, aggravated by the lack of storage infrastructure.
- Considerable improvement is required in infrastructure, e.g. storage facilities, cold storage, and loading and weighing facilities. Access to these facilities must also be provided to farmers.
- Lack of transparency in transactions between different stakeholders in the supply chain leads to inefficient price points and dramatic price fluctuations in agricultural produce.
- Farmer-based organizations should be strengthened, their participation increased, and technical assistance provided to reduce the number of intermediaries.
- Scientific standard operating procedures (SOPs) for harvesting, storage, and transportation must be designed to reduce PHL.

Table 5. State-wide losses in major fruit and vegetable producing states in India (Assocham, 2013).

Rank	State	Total loss (in crore[1] INR)
1	West Bengal	13,657
2	Gujarat	11,398
3	Bihar	10,744
4	Uttar Pradesh	10,312
5	Maharashtra	10,100
6	Tamil Nadu	8,170
7	Karnataka	7,415
8	Andhra Pradesh	5,633
9	Madhya Pradesh	5,332
Total India		212,552

[1] A crore denotes 10,000,000.

5. An innovative model in the supply chain for fresh fruits and vegetables

In the light of the inefficiencies and gaps discussed and the rapid growth of global markets that open up new retail opportunities in perishable produce, there is a vast scope to improve the supply chain of FFV. A key driver for increasing market efficiency in FFV will be shifting from subsistence agriculture to agri-business and linking farmers to retail chains (Dastagiri *et al.*, 2013). Moreover, it has been demonstrated that the efficiency of FFV supply chains increases as the length of the chain decreases. The post-liberalization era presents ample opportunities to empower farmers by introducing innovations in the supply chain. Focusing on the scope and building on the challenges, the proposed model focuses on increasing the efficiency of FFV supply chains by establishing PPCs and creating effective forward and backward linkages for the produce through PPCs by integrating a MIS.

5.1 Different components of the proposed model and their operations

Backward linkage (backward integration partner model) means connecting a farmer base of those cultivating fruits and vegetables and taking into account the production and area under major crops in the region where the PPC is established. Farmers bring their produce directly to the PPC or to the CC where it is weighed and sorted. The grades and their corresponding prices are communicated to the farmer through pull-over displays and boards. After a satisfactory evaluation of the product, payment is made electronically to the farmer.

In the PPC, produce will be sorted, graded, cleaned, and packed (made-to-order process model). Personnel will be trained to handle all operations related to managing the produce in the PPCs and to maintain cleanliness and hygiene in the center. These operations will help maintain produce quality, reduce PHL, increase the shelf life of the produce, and thus fetch a premium price in the market.

Forward linkage (made-to-stock process model) implies establishing a market for the fruits and vegetables processed in PPC centers. The centers will transport the produce to distribution centers or directly to retailers, from where it will be shipped for actual sale. The retailers can place their orders directly with the PPCs to prevent a mismatch between demand and supply. Since the PPCs are directly linked to the retailers, there is greater scope for direct sale to consumers, and a higher percentage of the consumer's rupee is received by the farmer. The consumers benefit since they can buy quality produce. The supply side is protected against price volatilities. A detailed representation of the proposed supply chain models for FFV is shown in Table 6. The different aspects of the model are discussed below.

- *The producer base*

This component in the model forms the backward linkage and is responsible for supplying the produce to carry on the activities of the PPC. The farmers are expected to plan their harvest accordingly in order to maintain supply schedules and also organize labor for harvesting activities. The PPC will procure the produce from the farmers to fulfil the demand of their customers (retailers/hotels, restaurants, and cafes (horeca)) and thereby match supply and demand. Farmers will also be provided with specific information related to their crops, market prices, weather forecasts and other information received from the state public extension service providers such as farmer's call center, Indian meteorological department and other crop-specific research information from the regional research centers through technical personals based at PPC.

- *Primary processing center*

The PPC and its associated CCs are responsible for the operation of the model. The CCs are responsible for checking the availability of the produce with the farmer, as specified by the orders, and quality and quantity specifications. After matching the supply and demand, the orders are allocated to the farmers, and logistical arrangements are made by the PPC to collect the produce. The producers, for their convenience, can either make use of paid transportation services from PPCs or take their produce to the CC in their own transportation.

In the PPC, the volume of the produce will be weighed and will undergo a cleaning process, as specified in the SOPs set by the PPC. The produce will then be sorted and graded according to the prescribed specifications. The processed produce will be packed and sent to the distribution center (DC). The DC will distribute the produce to different buyers. Sometimes, orders can directly be transported to the DC from the CC.

■ *Markets*

This is the component for the forward linkage of the model. Based on the demand assessment of different segments of buyers (preferences and past trends, season-wise analysis), the PPC will plan inventory and supply. The buyer (individual consumer/horeca/supermarkets) places an order at the DC or the PPC, and details of the information are transmitted through the entire supply chain for each of the components to execute their duties. Produce at the PPC is graded 'A', 'B', and 'C' based on quality. Grade 'A' produce is aimed at Tier 1 cities in South India where it will be sold to retail outlets and premium customers. Grade 'B' produce will be aimed at local shops and neighborhood stores in Tier 1 and Tier 2 cities. Grade 'C' produce will be sold to horeca and processing units on demand.

5.2 Market information system platform

The management of the whole model will be monitored through a digital platform. The MIS platform refers to the processing of information through computers and other intelligent devices to coordinate and support managerial decisions within an organization. The rationale for its inclusion in the model is described below:

- It integrates the complete supply chain into an ICT-based platform.
- It enables the maintenance of transparency in the flow of information across the supply chain and different stakeholders.
- There is a provision to evaluate the standards of the produce.
- It enables order cycle management and inventory management.
- There is a provision of ICT interventions for market integration.

The digital platform will be split into three modules for easy access by stakeholders in the project. The objectives of the three different aspects of the digital platform are as follows.

■ *Farmer platform*

Considering the dearth of technical information available during critical times to agricultural producers, particularly small and marginal farmers, this platform will help them to solve production-related issues with any-time available solutions. It is also envisaged to assist in informed decision-making with real-time information on crop markets and dynamics. The producers will be provided with crop production protocols for better crop management as well as extension services on demand, and market intelligence in the form of price predictions for making informed decisions regarding crop planning. With information readily available across digital platforms like mobile phone and computers, it will be very convenient to access critical information, techniques, and interventions at the required pace and time. This will reduce the time and cost generally involved in contacting extension professionals for the same service.

■ *Process platform*

Supply chains for FFV in India are highly fragmented, limiting the ways to transfer higher profits at the retail end to the producer end. The processing platform will address this issue by connecting stakeholders in the supply chain in order to increase transparency. The MIS platform will also ensure complete produce traceability from farms to market, ensuring quality, packaging, and safety issues. Furthermore, the forward/backward linkage among the stakeholders in the supply chain will ensure price as well as quality protection.

■ *Market platform*

The market platform will ensure producer-consumer connect, increasing price transparency. It will also increase the producer's share of the consumer's money by reducing the role of the middleman. By reducing produce handling at different points, PHL are also expected to be slashed considerably, thus increasing the supply of fresh produce. With multi-pronged benefits for both producers and consumers, the market platform is expected to provide a price advantage to both buyers and farmers.

Integrating the digital platform into the model will enhance the supply chain value of FFV (Figure 2).

5.3 Structure of the primary processing center and process flow of activities

The PPC has six components connected with collection points, which are the major source of fresh produce. Thus, setting up a process flow and SOPs for each of these components is important. A basic PPC framework with six components will be created, and operational guidelines will be framed and shared with PPCs. Since PPCs will handle different crops at varying capacities, specific crop processing lines will be considered. Crop and process line-specific SOPs will be in place along with those for other stakeholders like machine and equipment suppliers, PPC units, and logistics service providers. SOPs for the six components in the PPCs.

■ *Intelligence cell*

The nerve center of the PPC unit will support decision-making through its intelligence capabilities. A process will be in place to collect information, collate data, and take decisions. The automated platform requires primary and secondary information to be fed in to obtain insights or decision triggers to smooth business operations. This decision support system is expected to enhance the decision-making ability of producers to obtain better prices.

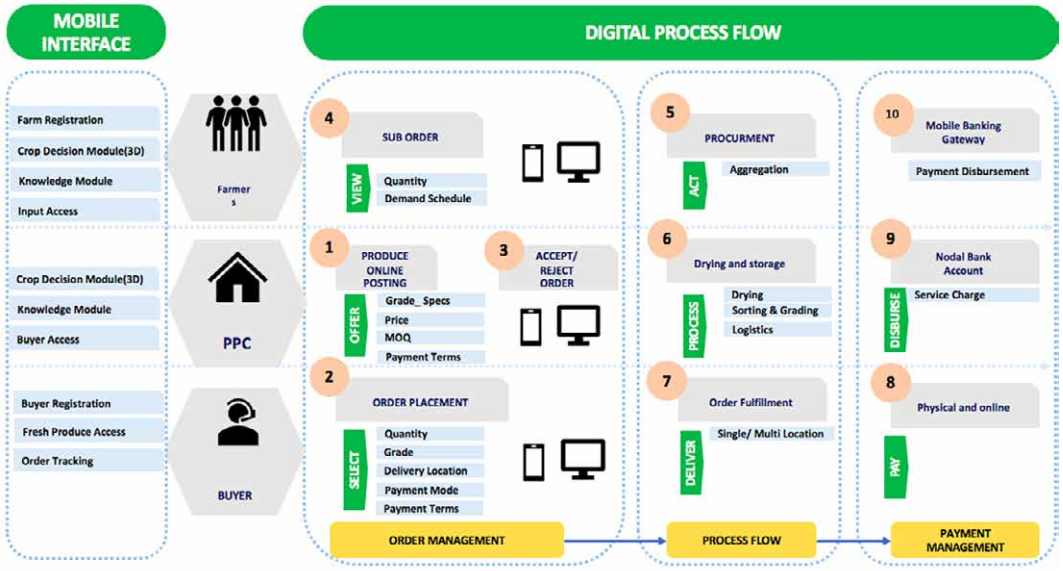

Figure 2. Digital process flow in a primary processing center.

■ *Primary processing unit*

This is a combination of a civil structure and handling machines, equipment, and tools. Machines specifically designed to handle cleaning, sorting, and grading will be installed in the PPCs to increase the shelf life of the produce as well as deliver according to set standards of quality and quantity. SOPs will be created to manage the PPCs.

■ *Storage unit*

Storage is one of the major challenges facing FFV producers due to the low shelf life of their produce. Improper storage raises the risk of rapid quality deterioration. The storage unit will be a structure with equipment and tools used to store processed products under controlled environmental conditions. The process is set to manage the desired temperature and environment to store fresh produce on a short- and medium-term basis.

■ *Packaging unit*

Packing units are where different kinds of primary and secondary packing materials and machines will be handled, run as a service to farmers and buyers. SOPs for handling, packing, and storing operations will be established, and resource personnel will be trained to maintain these SOPs. Since producers are the victims of market gluts that bring market prices crashing, increased shelf life of the produce will lead to higher profit margins for the producer farmers and FPOs.

■ *Market integration platform*

The marketing platform consists of physical and digital processes to be followed for farmer and buyer engagement, timelines, display and sales processes. The operational procedure is fixed and standardized to fit the different business models under which the PPCs will sell the produce.

■ *Logistics*

The framework and operational guidelines for the primary and secondary logistics provider will be created and supported through a handholding exercise. Logistics services will be at two levels, i.e. Level 1 and Level 2. Level 1 is for backward linkage for produce flow from farmer to a CC and from CC to PPCs. Level 2 is for forward integration that includes the flow of processed produce from PPCs to distribution centers and from there to consumers.

Transportation will occur in an Uber-like model. Via the ICT platform accessible through computers and mobile devices, farmers can find out the availability, type, and per kilometer rental price of the transport vehicle and book the vehicle anytime, as well as make use of the pre-booking facility. Farmers will be registered on the platform and will have credit scores. With the help of Level 1, the produce will be sourced from the CC to the PPC. The farmers will bring it to the CC and the model helps the farmer with aggregation planning. Payment for transportation services will be made after the produce is sold, and the producers' credit score will be negative until the produce is sold. With integrated information available at all stages as well as increased transparency, stakeholders will have greater accountability, making the system effective. The produce is subjected to sorting and cleaning processes in the PPC with the help of equipment and prescribed SOPs. The surplus volume of the sorted produce is stored. Based on real-time price and quality specifications, the sorted produce is graded and packed for distribution to buyers. The price discovery mechanism is put in place by the MIS platform. Secondary logistics are arranged for orders to be shipped to buyers from the PPCs.

The proposed model provides multiple advantages over the existing challenges in the FFV supply chains as mentioned in Table 7. It will result in the streamlining of the currently highly unorganized supply chain of FFV, following the integration of multiple stakeholders and an in-built monitoring system in the form of the

Table 6. Detailed representation of the proposed supply chain for fresh fruits and vegetables (FFV).[1]

Processes	Backward integration model		Made-to-order process model			Made-to-stock process model		
	Production base	**Collection centers**	**Primary logistics**	**PPC**	**Packaging**	**Price discovery**	**Secondary logistics**	**Consumers**
Stakeholders/ ownership	Local farmers	Producer aggregates, preferably FPOs	Local entrepreneurial youth/existing transportation services	Producer aggregates, preferably FPOs		PPC	Local entrepreneurial youth/existing transportation services	• Premium customers • Retail chains • Neighborhoodstores • Horeca • Processors
Innovative intervention	Introduction of advanced crop production protocols	Village-level collection of fresh produce: • to reduce post-harvest handling • for systematic aggregation of produce	• Uber-like model for pre-booking of transportation vehicle; need-based service with price display • Service accessible on digital and mobile devices	Introduction of cleaning, grading, sorting, and packaging of FFVs for increased shelf life and targeted marketing	Packaging of produce based on target market to optimize operational cost and increase returns	Price discovery is guided by market forces and done by PPC matching supply and demand information from both backward and forward linkages	• Uber-like model for pre-booking of vehicle; need-based service with price display • Service accessible on digital and mobile devices	Categorization of consumers and grading of produce to meet specific demands, creating a niche market for each grade of produce
Incentives	• Increased quantity of sold produce • Higher income	• Reduced transportation cost for producers • Collective marketing	• Greater entrepreneurial and employment opportunities	• Increased shelf life of produce • Greater quantity sold • Better returns	• Increased shelf like • Increased attractiveness of produce • Brand experience for consumers	• Higher profit to FPOs • Optimum price paid by consumers • Greater share of the producer in the consumers' money	• Greater entrepreneurial and employment opportunities	• Better quality of produce • Produce matched to needs • Less price fluctuation at the consumer end • Greater availability of quality produce
End-to-end supply chain visibility platform	IT platform integration from producer to consumer end for increased transparency Better monitoring from production to marketing processes Better management of product flow, financial flow, information flow, value flow and risk flow in the supply chain							

[1] FPO = farmer producer organisations; PPC = primary processing center.

state-of-the-art MIS that will ensure the efficient flow of all processes in the supply chain. PHL are highest at handling and storage stages due to lack of knowledge of scientific processing. The proposed model will use a multi-pronged approach and make critical interventions (setting up of processing/packaging and storage units) targeting these stages to reduce losses. Direct linkages with horeca, consumers, and retailers will be established through appropriate backward and forward linkages to correct inefficiencies in the supply chain. With direct linkages between consumers and producers, price differences will also decrease, increasing the profit margin for the producer. Proper management will assure a greater supply of produce to the consumer in the desired quantities and quality, fetching a better price. The decision support system, moreover, integrates an extension component with easier access through ICTs, thus removing the cost involved in extension services and ensuring timely services. MIS also increases transparency in the supply chain by keeping track of physical as well as financial transactions within the supply chain.

The proposed model will be managed by producer aggregates/FPOs for better management and accountability. This will lead to active participation and ensure transparency. While the whole operation is proposed to be overseen by FPOs or farmer bodies, local educated youth will be employed to oversee the operations of the CCs and PPCs. Skilled and unskilled labor required for PPC operations, transportation, handling, and packaging, will be sourced from local communities, especially women and youth, to increase employment among disadvantaged sections. Transportation, packaging, and related activities will provide entrepreneurial opportunities to local farm and non-farm youth, thus increasing income-generating activities, and build better communities in the long run. With the operations managed by producer aggregates, a significant number of intermediaries will be eliminated from the supply chain, resulting in better returns and profits to be distributed among member farmers.

Table 7. Existing challenges in the fresh fruits and vegetable supply chain that will be addressed through the proposed model.

Existing challenges	The mechanism to address through proposed model
Lack of awareness leading to poor management practices at the farm level	ICT integrated decision support system On-demand extension service Price and market forecast along with historical price trend provided to farmers for better decision making Weather and agronomic advisory
Improper harvesting time and method	Crop production protocols for better management practices
Excessive and improper handling	Streamlined handling of produce through proper transportation services Reduced handling of produce due to the removal of multiple intermediaries
Inadequate storage and seasonal glut	Cold storage to increase the shelf life of the produce, reduce market glut and receive a better price
Lack of proper transportation	Efficient transportation services from CCs to PPCs, and from PPCs to consumers Uber-like models help farmers chose the model of vehicles based on requirement and pre-book them before harvesting
Logistics	Forward and backward market integration ensures the efficient flow of produce and finances across the value chain without causing high price fluctuations
Market intermediaries	Fewer market intermediaries and greater control of marketing channel to producers through producer groups/FPOs
Visibility and consumer awareness	Produce being sold directly to consumers will increase transparency, ensure better quality and reduce transaction cost along the chain Graded produce with target market will bring in better profits because of demand-based stratification

With crop production and handling protocols provided to the farmers, easily traceable and pre-booked vehicles to transport fresh harvest, and CCs equipped with required facilities, the model reduces the chances of PHL. Marketing efficiency is another major challenge in the supply chain where more intermediaries mean a reduced share going to the producer, higher prices for consumers, and increased handling leading to losses in produce. Forward linkages in the proposed model will ensure enhanced marketing efficiency and a greater share of the consumer's rupee reaching farmers. With the whole process managed by producer aggregates and increased end-to-end visibility through an integrated IT platform, the produce is expected to move faster, through fewer hands, to be packaged as needed, and reach the end consumer more efficiently. The model will also lead to the following long-term impacts:

- With a proper infrastructure in place, producers will be able to harvest their produce in a phased manner without compromising on quality and avoid distress sales. This helps in reducing price volatility and loss of FFV, and increases affordability and availability throughout the year.
- A streamlined supply chain can impact farmers' income in multiple ways – better management practices leading to higher yield, quality produces fetching a better price, reduced distress sale, higher profit margins due to direct sale – leading to higher income and livelihood security.
- Operations like transportation, packaging, quality input supply, and advisory services along the supply chain will provide entrepreneurial opportunities, thus helping the rural youth with self-employment.

The long-term impact of a streamlined supply chain can also result in increased nutrition security of rural populations due to higher income and a diversified remunerative livelihood.

6. Conclusions

A fairly detailed literature review of the efficiencies of various marketing channels of FFV in India highlighted the importance of organized retail in increasing producers' share in consumers' money. A major challenge in the agriculture sector has been PHL aggravated by poor crop management and harvesting practices at the farm level, lack of storage infrastructure, excessive handling, and transportation challenges. The proposed model is aimed at addressing these challenges and streamlining the supply chain for better returns and reduced losses. The model focuses on crucial sections of the FFV supply chain and addresses the major challenges across the main FFV-producing states in India. The applicability of the model thus increases across the country, while being flexible enough for required context-specific modifications. As the management of the FPOs are proposed to be assigned to producer aggregates/FPOs, this will increase accountability and transparency, giving increased bargaining power to producers. The digital platform will provide information about pre- and post-harvest technologies with respect to different crops to maintain quality standards of the produce and reduce PHL. Increased transparency, fewer price fluctuations, and better quality produce will benefit the consumers as well. Overall, the proposed model will increase the efficiency of the FFV supply chain and has practical implications for agribusiness management and policymakers concerning FFV supply chain development in India.

Conflicts of interest

We declare no conflict of interest.

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