Development of novel strategies for designing sustainable Indian agri-fresh food supply chain

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Abstract. Traditional Indian agri-fresh food supply chain (AFSC) is unorganized and controlled by a large number of intermediaries, causing it to be unsustainable from the farmer (low profitability) to the customer (not getting quality product even after paying a high price). The purpose of this paper is to propose novel strategies for designing a sustainable Indian AFSC. Authors identify shortcomings as well as strengths, weaknesses, opportunities and threats (SWOT) of the Indian agriculture system through the literature survey. To improve overall performance of this chain, authors have developed eighty strategies by incorporating SWOT into TOWS (threat, opportunity, weakness and strength) matrix. They define four key objectives to mitigate the aforementioned problems. In this paper, twelve strategies are shortlisted from existing ones on the basis of fulfilling a maximum number of objectives. The shortlisting of strategies is further verified by evaluating strategies using performance measures (PMs) in sustainability dimensions, which revealed that the twelve chosen strategies dominate over other strategies. The shortlisted strategies are mainly focused on improving the economic dimension of AFSC by satisfying maximum number of objectives and PMs. The chosen strategies pledge for the optimum and most feasible ones to be recommended for managers/researchers towards redesigning the AFSC. The proposed viable strategies are expected to reform the conventional Indian AFSC by designing sustainable supply chain (SSC). The outcomes of this work will provide clear guidelines for researchers and policy makers to make sustainable agriculture.

Keywords. Agri-fresh food supply chain; sustainable supply chain; SWOT analysis; strategy development.

1. Introduction

Agriculture supply chain (SC) is a vast area, which includes varieties of products like vegetables, fruits, flowers, milk, spices, pulses, cereals, oilseeds and cotton. Thus, it is a challenging task to explicitly differentiate the chain for various agricultural products or to cover all products in a single SC. Therefore, when we consider all the processes from production to delivery of short-shelf-life produce¹ such chain is referred as an agri-fresh food supply chain (AFSC) [1]. As compared with other SCs, AFSC reveals special characteristics like perishable nature of the item, seasonal production, variability in quality and quantity as well as special requirements for logistics services [2].

Conventional Indian AFSC consists of farmer, agent, wholesaler, retailer and customer. The functioning of this SC is as follows: farmers grow crops and bring their produces to a regulated market (Mandi²) to sell, where agents do an open auction and wholesalers buy these items through bidding the highest price in auctioning. Thereafter,

wholesalers grade and sort these items and supplies to a retailer. Finally, the retailer (may be a hawker, roadside shop owner, etc.) sells the items to customers [3–6]. This SC is only for a region (regulated market) and many times, demand and supply are normally unmatched in a region. Owing to this, wholesalers of a market purchase (sell) from (to) other wholesalers of a different market, which further increases the complexity of SC. The complexity also increases in Indian AFSC due to a large number of small farmers and scattered production [6].

In Indian AFSC, the activities that are executed only in a regulated market are ruled by Agriculture Produce Marketing Committee (APMC) under state government regulations [5, 6]. Unfortunately, the chain is executed by unorganized large number of intermediaries [3]. Also, there is lack of coordination among the players in the chain [7, 8]. Therefore, these intermediaries play a prominent role in making the AFSC inefficient as well ineffective by

¹Produce means agricultural product grown by farmers.

²Mandi is a regulated market where farmers, agents and wholesalers gather for completing their sale and purchase.

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controlling the flow of products, funds and information. Thereby, farmers do not receive adequate price of their produce and customers do not get quality product even after paying high price [8, 9].

The expectations of farmers as well as customers have been changed due to development in information technology (IT) and they want in lieu of what they have invested and paid, respectively. Many times, farmers agitate against the government for demanding better price of their produces [10, 11]. Ensuring acceptable price of produce for the farmers and the customers is a major hurdle as well as a big question for the government. Therefore, it is an urgent requirement to deliver products such that farmers receive remunerative price of produce and simultaneously customers also get quality product at minimum price.

To meet these expectations, it is required to reform traditional Indian AFSC by identifying suitable strategies for designing sustainable supply chain (SSC). Three dimensions of sustainability (i.e., economic, environmental and social) need to be addressed in strategic planning of the chain [12]. The strategic decision-making processes require a comprehensive knowledge of an existing SC to propose strategies for designing SSC [13]. Therefore, we first identified drawbacks as well as strengths, weaknesses, opportunities and threats (SWOT) through available literature followed by developing strategies using TOWS (threat, opportunity, weakness and strength) matrix. Out of these, some of the most viable (optimum as well as feasible) strategies have been short-listed for designing sustainable Indian AFSC. The aim of this work is to suggest suitable strategies so that the existing Indian AFSC can be re-designed. Hence, the present work will guide researchers and policy makers in designing sustainable Indian AFSC.

The following steps are used in the manuscript to achieve the proposed aim:

- to identify internal (S, W) and external factors (O, T) for Indian AFSC,
- to develop strategies using TOWS matrix,
- to classify the developed strategies for better managerial interpretation,
- to shortlist most viable strategies out of the developed and
- to verify shortlisting of strategies using performance measures (PMs).

Structure of this research paper is as follows. Section 2 presents systematically literature review and identification of problems in Indian AFSC. Process of strategies development, TOWS matrix and steps of research methodology are explained in section 3. Section 4 covers SWOT analysis, strategies development and classification of developed strategies. Shortlisting of strategies and verification of shortlisting are presented in section 5. Section 6 reports key findings of the present work and lastly section 7 concludes the research work.

2. Literature review

To investigate the state-of-the-art, major shortcomings and research gaps of Indian AFSC, the literature review section is divided into six parts as follows: first part highlights the importance of Indian agriculture, second part explains some recent research articles and third part presents review papers. Some relevant case studies have been grouped in the fourth part and the fifth part discusses the main drawbacks of AFSC. Finally, the sixth part summarizes the section by identifying the research gaps in existing literature. As a further outcome, this section helps in determining SWOT of the system given in section 4.

India has 11.3% of arable land of the world and has been reported as a top-ranked country in the world for huge agricultural production for various produces [14]. Indian agriculture sector contributes around 12.4% in GDP [15] and about 58% of population in India depends on it [16]. Attracted by this, many multinational companies have entered in agricultural sector to take advantage of opportunities like processing, marketing and exporting of agricultural products [5]. It has ample capabilities to stimulate the prosperity of rural households, generate employment and involve industries by reforming agriculture sector [16, 17]. Therefore, nowadays the Government of India is focusing on agriculture sector and has introduced an e-NAM (National Agriculture Market) portal to connect all players of the chain [18]. Recently 'World Food India 2017' has been organized by Ministry of Food Processing Industries to provide opportunities for investment and trade in food processing as well as in retail sector [19].

Perusal of available literature reveals that only a little attention is paid by researchers in the area of AFSC. As discussed in the previous section, auctioning is administered by traders in a regulated market. Therefore, Viswanadham *et al* [20] proposed an electronic exchange to reduce their existing monopoly. Panda and Sreekumar [21] empirically found that farmer's market selection for selling their produces depends on market information, availability of market infrastructure, guaranteed market, value and grade of produces. Adoption of innovative agricultural practices by farmers with variation of land holdings is empirically studied by Ali [22] at different stages of cultivation and post-harvest management as well as sales and marketing practices in Uttar Pradesh state. Hegde and Madhuri [6] conducted a study on AFSC of Maharashtra and Karnataka states of India. They find major deficiencies such as the lack of grading, inadequate transport facilities, presence of a large number of middlemen, mismanagement in regulated markets and inadequate market information facilities. In another set of papers [7, 23, 24] various causes of food wastage are identified in AFSC and major causes include a large number of intermediaries, poor transportation, lack of linkage among members and lack of standardized quality control procedures. They suggest

formulating appropriate strategies to minimize the losses in the distribution. Saorín-Iborra and Gustavo [25] investigated the supplier behaviour and increase the satisfaction level of the customer/retailer.

A few review papers are focused on current research status of AFSC. Rajurkar and Jain [26] review articles and recommend formulating strategies for improving food SC. The authors suggest designing a suitable information system and developing effective approaches to reduce wastage as well as managing the relationship between customers and farmers. Samuel *et al* [4] compare AFSC evolution, procurement, marketing strategies and business models of developed versus developing countries. They find that UK, USA, Australia, New Zealand and China have well-organized AFSC as compared with India, where it is still in the nascent stage of reformation. Shukla and Jharkharia [1] systematically reviewed literature on AFSC for pointing the key causes of food wastage. The authors report the existence of a large number of intermediaries as well as inefficiencies in storage, handling and transportation. Further, they recommend working in the area of demand estimation, information sharing between players and distribution network design of the Indian AFSC. In a recent review article [27] the authors highlighted main problems of AFSC as follows: exploitation by middlemen, high marketing cost, fragmented AFSC players, poor marketing infrastructure, high wastage of produces and poor post-harvest methods. Bag *et al* [28] described the retail 4.0 and the impact of e-commerce with satisfaction of customers' demand.

In recent years, some organizations/researchers have started re-designing an effective AFSC to reduce wastage and meet customer demand at minimum cost. Nisarg Nirman Agro Products Private Limited proposed a model for social farming in 1997 [29]. It provides superior quality exotic vegetables at competitive prices to five-star hotels and premier clubs as well as retail outlets by including farmers, consultants and suppliers. Another redesigned vegetable SC named as 'Samriddhi' was introduced in 2008 by Kaushalya Foundation in Patna (India) [30]. The main objectives were to organize and professionalize small farmers along with street vendors. Kundu [9] suggested 'Project Samridh Bharat' to reduce intermediaries in AFSC by considering deterministic data like price, transportation cost, etc. However, he ignored some of the crucial aspects like demand of customers, packaging, routing of vehicle and seasonality in production. Sihariya *et al* [31], comparing organized retail models of Benison store, Hypercity and Reliance Fresh, found that there is lack of integration with farmers, transportation and packaging facilities. Zhang *et al* [32] described the optimal collaboration of transportation to supply the cargo to retailers.

Based on the literature survey, we identify and group the main shortcomings of traditional Indian AFSC as explained here. (1) According to Rajkumar [3], 97% of *Indian AFSC is unorganized*. (2) An AFSC is run by *a large number of intermediaries* [3, 7, 8]. (3) There is no direct interaction

between farmers and customers. Therefore, farmers receive only about one-third of the price paid by customers [8, 9]. In another survey, NSSO [33] has reported that 40% of small and marginal farmers want to quit farming due to *low profitability*. Many times, farmers are not able to achieve the break-even point in consecutive seasons. Owing to this they are drawn by huge debt and unfortunately forced to commit suicide. According to the NCRB [34] report, 8,007 farmers committed suicides during the year 2015. (4) Another identified major problem is *high wastages of produces*, which is in the range of 15–20% due to improper distribution network [7, 35, 36]. (5) Resulting from these shortcomings, *customers do not get quality produces* even after paying high prices [6, 8]. The main three shortcomings, namely unorganized AFSC, large number of intermediaries and wastages of produces, need to be tackled for sustaining players (particularly farmers) in the AFSC.

It is observed from the literature that the unorganized AFSC and a large number of intermediaries cause farmers' low profitability and wastages of produces. The unorganized AFSC and a large number of intermediaries make SC unsustainable from farmer (low profitability) to customer (not getting quality product even after paying a high price). There is a huge possibility (within the system) as well as opportunity (external) to reform Indian AFSC by designing the SSC to achieve agricultural sustainability [8, 31, 37–39]. Unfortunately, none of the previous researchers have proposed strategies to resolve the shortcomings, which further lead to the re-designing of an SC. Therefore, to fulfil the research gaps, it is highly warranted to develop optimum as well as feasible strategies by targeting afore-mentioned issues.

3. Research methodology

This section describes the process of strategies development, some recent research papers related to strategies development using TOWS matrix and steps of research methodology incorporated in this paper.

Development of strategies for any system is a tedious task and requires practical, social and economic knowledge of the same. It is also observed that strategists must have good knowledge as well as innovative ideas to explore new possibilities in the system. Further, knowledge about feasibility and execution of a strategy are required for choosing the viable strategies. Good strategies lead the system to new heights and its effect can be seen for a long time. In the literature we found TOWS matrix to be an effective as well as widely used tool for strategy development. Some recent research papers on the development of strategies for various cases are presented here.

The TOWS matrix is a variant of SWOT analysis and was proposed by Weihrich [40] for strategies development of an organization. The SWOT analysis focuses on identifying internal (strengths, weaknesses) and external factors

(opportunities, threats) while the TOWS matrix provides guidelines for strategies development using different combinations of these factors (SO, ST, WO and WT). In review papers [41, 42], the authors examined history, evolution and application of SWOT/TOWS analysis in different areas. The method has been successfully applied by various researchers to develop strategies for the SC. For example, Rauch [43] developed timber mobilization strategies for Austrian forest owner co-operations of a wood supplier. Morris and Mare [44] developed collaborative marketing strategies through focus group study for a specific group of sheep farmers in Namibia. In another set of papers, the ranking of developed strategies has been done by pair-wise comparisons using MCDM technique in different areas like mining sector [45], natural resources management [46] and manufacturing industry [47]. Moghaddaszadeh *et al* [48] identified and ranked SWOT by collecting data from Avid food industry in Iran.

Research methodology of this paper is divided into 7 steps. In step-1, SWOT analysis identifies internal and external factors affecting the agriculture SC from literature survey. These factors are systematically presented in TOWS matrix form and strategies are developed in step-2. The developed strategies are classified and described in distinct groups in step-3. In step-4, objectives to be achieved by the SC are defined based on identified shortcomings of Indian AFSC. The objective(s) fulfilled by each of the strategy is (are) identified based on the most suitable strategies shortlisted in step-5. PMs as proposed by Aramyan *et al* [49] are first modified in the sustainability dimensions in step-6 and then verification of the shortlisting of strategies using PMs is presented in step-7. The seven steps of research methodology are executed to develop the viable strategies as follows. Step-1, step-2 and step-3 are carried out as described in section 4 to develop the strategies. The remaining steps (i.e., step-4, step-5, step-6 and step-7) are performed in section 5 for shortlisting of strategies followed by verification of the shortlisting of strategies.

4. Strategies development

Step-1: SWOT analysis

Authors comprehensively review the various published articles [40, 43, 47, 50–52] and identify possible SWOT of the system. These possible factors of SWOT are summarized as follows.

- Strengths: vast administrative network, strong presence in the market, resources availability and financial structure.
- Weaknesses: inadequate infrastructure, poor distribution channels, improper management culture, policies, old age equipment (technology) and employee.

- Opportunities: government encouragement, technological enhancement and improvement in distribution facilities as well as growing prosperity and population.
- Threats: Various uncertainties, natural calamities, energy shortage and competitive environment.

Based on these suggested guidelines, authors analyse the Indian AFSC and identify SWOT as discussed in the following paragraph.

Authors study the working of existing Indian AFSC from available literature and prevailing conditions. To understand other practical aspects of the chain, authors visit nearby agricultural markets (Mandi) and interact with players. Further, SWOT of Indian agriculture system are identified through literature survey of guidelines discussed earlier. Strengths of similar types are kept together and merged into a single representative strength. Hence identical strengths are reduced into a small number of representative strengths. Similarly, weaknesses, opportunities and threats are reduced into a small number of representative weaknesses, opportunities and threats, respectively. The complete exercise of finding and combining the internal factors (strengths, weaknesses) as well as external factors (opportunities, threats) is shown in tables 1 and 2, respectively.

Step-2: Strategies development

Strategies are developed using TOWS matrix with the help of guidelines suggested by Khatri and Metri [47]. Strategy development is a continuous improvement process until the most relevant strategy is developed for enhancing the overall performance of the chain. Thus, authors identify the best use of strength (S1) by taking advantages of opportunity (O1) in a specific cell (S1_O1) and repeat the process for all cells of SO combination. Similarly, we recognize the best utilization of strength (S1) to overcome threat (T1) in a cell (S1_T1) and repeat the process for all cells of ST combination. Likewise, planners ascertain to mitigate/remove the weaknesses through taking advantages of opportunities as well as overcoming threats in WO and WT combinations respectively. The complete exercise for the development of total eighty strategies are depicted in tables 3 and 4.

Step-3: Classification of developed strategies

The developed eighty strategies are grouped for recognizing their associated work direction, which helps in subsequent stages. The strategies pertaining to the same area/domain (column 4, table 5) are grouped and named with their customary heading. Thereby, ten distinct groups are obtained as shown in column 3 of table 5. Further, these classified groups are presented into four different aspects according to the practicality/functionality of each distinguished group. These aspects are technological, social, agricultural and governmental, displayed in column 2 (table 5).

Table 1. Internal factors.

Code	strength	Description of strength	References
S1	Significant contribution of agriculture sector in development of the nation	1. Contributes about 12.4% of the GDP 2. Employs about 58% of the population	[15] [16]
S2	Availability of resources for huge agricultural production	1. Huge resources are available 2. Second largest area under cultivation in the world 3. World's largest producer of many fresh items	[8, 38] [16] [14, 24]
S3	Uplifting the trend of educating rural masses	1. Involvement of young educated people in agriculture 2. Increasing smartphone use in rural India	[15] [53]
S4	Conducive climate for growing diversified products round the year	1. All 15 major climates of the world exist in India 2. Possesses 46 of the 60 soil types found in the world 3. Presence of diverse climates and ecosystems (agricultural biodiversity)	[8, 16] [16] [54]
S5	Government schemes to support farmers	1. Subsidies in fertilizer, farm machinery, electricity bill, etc. 2. Loan facility, crops insurance scheme, etc.	[16] [16]
Code	weakness	Description of weakness	References
W1	Large number of small-farm-holding farmers	1. Small farm holdings and mostly family operated 2. Scattered production	[3, 15] [6, 31]
W2	Poor design of AFSC (Inefficient flow of products, funds and information)	1. High postharvest losses in the distribution 2. Low profit margin to farmers 3. Large number of intermediaries	[7, 8, 36] [8, 9] [7, 8, 24]
W3	Poor infrastructure of re-distribution points	1. Markets are not well developed 2. Poor linking of small villages to the markets 3. Lack of cold storages, reefer vans and ripening chambers	[8] [8, 31] [7, 8]
W4	Lack of modern technology for managing AFSC	1. Less use of sorting and grading methodology 2. Lack of demand estimation and information sharing 3. Missing link between farmer, consumer and researcher	[7] [23, 31] [8]
W5	Lack of farmers' interest towards secondary agricultural activities	1. Lack of farmers' attention in postharvest activities 2. Improper sorting, grading and packaging of produces	[8, 23] [8, 31]

Analysis of table 5 suggests the following. (1) Technological aspect needs attention by engineering economics community for further work. (2) Strategies under social aspect need to be tackled by the researchers working in the area of social economics. (3) Agricultural scientists can explore agricultural aspect to enhance farming and value-added productivity. (4) The various governmental agencies like planning commission, APMC board and agricultural departments require focusing on governmental aspect for upgrading the AFSC. One important observation that can be noted from table 5 (column 5) is that most of the strategies under technological and social aspects get the advantages of opportunities by overcoming the weaknesses. On the other hand, strategies under agricultural and governmental aspects defeat most of the threats using strengths.

Most of the governmental strategies are developed from existing established schemes, i.e., strength (S5) and opportunity (O3) combinations. The strategies (S5O4, W4O3, S5T1, S5T3 and S1T1) mainly focusing on expansion of various existing schemes to cover the maximum number of farmers and crops [16, 65], that is an operational aspect of system. A few strategies like

introduction of new educational modules (S3O3), formation of farming zone (W1O3) and development of eco-friendly farming system (S5T2) are required administrative initiatives without much support from government side. Development of infrastructure (W3T2 and W3T3) is a prime and basic responsibility of government, which leads to the overall growth of the nation. Government of India has already started various schemes for doubling the farmers' income by 2022; they show the government's commitment for betterment of agriculture sector.

5. Shortlisting of strategies and verification

Step-4: Defining objectives

The objectives to be achieved by the SC are defined as the shortlisting criterion. These four important objectives are defined based on major drawbacks as identified in the literature review (section 2). These objectives are attempting to mitigate the problems of Indian ASFC. These objectives followed by their necessary descriptions are given here:

Table 2. External factors.

Code	opportunity	Description of opportunity	References
O1	Continuously increasing demand of fresh produces	1. Demand for fresh items is increasing day by day	[16, 38]
O2	Technological advancement	2. Uniformly purchasing power and awareness are also increasing	[8, 55]
		1. Improvement in processing technologies	[8]
		2. Rapid growth in the smartphone users and it allows access to the internet easily	[55, 56]
O3	Government initiatives to gear up agriculture industry and to boost the quality of life	1. FDI in agriculture	[16, 55]
		2. Government supports for processing industries and warehouses	[16]
		3. Government schemes – Smart City, Digital India, etc.	[57]
O4	Increasing interest of private industry in agriculture sector	1. Organized retail sector shows interest in AFSC	[5, 38]
		2. Innovation in retail formats	[55]
		3. Huge opportunities emerge as the leading global food supplier	[8]
O5	Availability of wide range of distribution networks including transport facility	1. Varieties of retail formats exist in India	[17]
		2. Fastest growing markets in the world	[17]
		3. Second largest road network in the world	[58]
		4. Varieties of freight are possible	[59]
Code	threat	Description of threat	References
T1	Over- and underproduction due to improper information of demand and supply	1. Lack of demand–supply integration	[1, 7, 8]
		2. Lack of coordination among farmers	[7]
T2	Declining land holdings, fertility and farmers' interest in farming	1. Decrease in size of land holdings	[60, 61]
		2. Land degradation	[60]
		3. Declining interest of farmers in agriculture	[33]
T3	Unavoidable circumstances due to weather variation	1. Climate change and global warming	[60]
		2. 57% rain-fed agriculture	[62, 63]
		3. Abrupt variations in weather	[64]

Objective [†]	Identified problem(s)
(a) Minimizing distribution lead time	Unorganized AFSC and large numbers of intermediaries
(b) Reducing wastage in distribution	High wastages of produces
(c) Increasing farmers' profit	Low profitability of farmers
(d) Enhancing customers' satisfaction	Customers do not get quality products

[†] These objectives are henceforth referred to as (a)–(d) as defined herein.

The first objective is minimizing distribution lead time, which is defined as the total time required for delivering fresh products from farmers to customers [3]. The fresh items deteriorate due to high lead time as they reach the customers [8, 31]. Rajkumar [3] has explained distribution lead time as an indicator of efficiency and sustainability. Unorganized intermediaries make AFSC inefficient, resulting in less effective flow of products, funds and information. The second objective is reducing postharvest losses (15–20%) due to improper handling, transportation and storage [7, 8, 36]. The price received by farmers is very low and it is about one-third of what is paid by customers [8, 9]; hence, increasing farmers' profit is the third objective. The Government of India also

has made national agenda named as 'Doubling Farmers' Income by 2022' [65, 66]. Finally, the fourth objective, enhancing customers' satisfaction, is defined to attract large number of customers in the chain. The customers' satisfaction is an important parameter for designing a successful SC and it can be enhanced by providing quality products and services at the minimum possible price [67]. According to Chopra and Meindl [68], the proposed objectives (a)–(c) are related to the efficiency while objective (d) is related to responsiveness side of the SC.

Step-5: Shortlisting of strategies

The next task is to find the most essential and urgent demanded strategies from the developed ones that have the highest impact to sort out the problems of Indian AFSC. For this purpose, the formulated strategies are shortlisted in order to remove/mitigate the problems faced by the Indian AFSC using four objectives (defined in step-4). This shortlisting criterion implies insisting on choosing strategies that have the highest impact on solving the current problems of the chain; therefore, it makes the selection more realistic. According to Agricultural Sustainability Institute [69] and Bloemhof and Mehmet [70], agricultural sustainability can be achieved in AFSC by reducing distribution lead time and wastage of produces as well as ensuring the active participation of farmers and customers.

Table 3. Strategies using strengths.

SO strategies					
	S1	S2	S3	S4	S5
O1	Top-most priority in supplying quality (fresh) produce to the consumers	Supply customized produce in terms of quality and variety	Involvement of trained people in AFSC to meet urban needs	Supply seasonal consumable products as per regional demand	Emphasis on supply of policies centric products by identifying potential customers
O2	Latest technological connect in AFSC activities	Emphasis on lowering production cost to increase farmer's profit	Optimum utilization of e-commerce activities	Establish cold supply chain	Enhancement of farmer's technological awareness to yield more produces
O3	Establish processing industries	Monitor and control AFSC activities	Design new education modules/courses for post-harvest management	Design SC for food industry based on their input food items	Collaborate with municipal corporation to supply produces
O4	Modify existing SC network for supplying fresh produces efficiently to consumers	Develop model for demand–supply integration	Automation of AFSC activities	Select product mix to ensure the uniform availability of the product round the year	Fix minimum support price to ensure farmers profit margin
O5	Redesign existing AFSC to increase availability of items with faster response to fulfil demands	Timely sorting and packaging the goods in order to minimize the damage	Design an IT-based logistics system	Use refrigerated warehouses as well as vehicles to deliver fresh produces	Model government registered farmers' cooperatives to distribute items
ST strategies					
T1	There should be a governing body for production planning and fixing minimum support price	Open facilities for storing items as either raw or as primarily processed food	Integrate demand and production of fresh produces	Production of exotic vegetables	Government should provide support to most needed and low production items
T2	Involve farmers in AFSC activities	Production enhancement through organic and multi-layer farming	Create jobs to manage AFSC activities based on qualification	Incorporate animal husbandry with farming	Develop eco-friendly farming equipment and incentivized users
T3	Grow variety of simultaneous crops to minimize the effect of uncertainty	Optimum utilization of agricultural resources	Prediction of accurate and timely weather and accordingly decide	Promote environmental research and innovation in farming methods	Use geographic information system (GIS) to identify affected farmer for compensation

Therefore, these objectives force shortlisting of the most required strategies for designing SSC. The objective(s) fulfilled by each of the developed strategies is (are) identified by brainstorming session and shown in column A of table 6. The strategies that satisfy three or higher number of objectives are shortlisted as the proposed strategies (bold letters in table 6) for designing sustainable AFSC.

Step-6: Modifying PMs

The shortlisting of strategies is verified using PMs in sustainability dimensions in step-7. Sustainable PMs evaluate the SC in three important dimensions (i.e., economic,

environmental and social) and these evaluations help in determining the most feasible strategies by dealing with the real situations of the chain [13]. We did not come across suitable sustainable PMs for AFSC in the literature. Therefore, PMs related to AFSC [49] are first organized into sustainability dimensions according to the guidelines proposed by Cetinkaya *et al* [13]. Later, a few more PMs are also added to complete the list and are explained in table 7.

Step-7: Verification of shortlisting

Verification of shortlisting of strategies is done with the help of modified PMs in sustainability dimension. For

Table 4. Strategies overcoming weaknesses.

WO strategies					
	W1	W2	W3	W4	W5
O1	Integration of small farmers	Formation of robust transportation model	Develop a model for cooperative marketing	Develop appropriate information sharing model to meet demand	Design feedback system for an AFSC
O2	Optimum utilization of IT to connect farmers	Use smart transportation in an AFSC	Use cross-dock to supply fresh items	Develop an IT model to connect different players of AFSC	Organise training and workshop on use of modern technology in AFSC
O3	Motivate farmers to form a special farming zone	Encourage farmers for specialized tasks in AFSC other than farming based on their capability	Form farmers' cooperative and establish their selling points in urban areas	Design user-friendly communication tools, web portals under government schemes to help farmers	Impart latest postharvest technology to the farmers
O4	Provide transportation facilities to the farmers	Establish an AFSC sub-centre in rural area	Identify, design and establish the re-distribution points	Develop an IT-based model to organize an AFSC	Establish small scale processing plants in rural area
O5	Design collaborative transportation model for Indian AFSC	Find optimum operational decisions of an AFSC through research	Optimize number and locations of re-distribution points	Use tracking and tracing of vehicles in AFSC	Collect produces from villages (farms) and deliver it at demanded location
WT strategies					
T1	Farmers should focus on diversified farming system	Use contract farming	Use e-commerce in AFSC	Share demand and supply information between partners using IT	Design farmers' co-operative society for distribution and production of produces
T2	Promote animal husbandry to develop bio-fertilizer	Involve easy operational activities in an AFSC	Provide world class facilities in the AFSC	Use e-auctioning in the AFSC	Give award and grade to the outstanding/ eminent farmers
T3	Use polyhouse farming	Design a sustainable AFSC	Provide sufficient facilities at re-distribution points to avoid inconvenience	Train farmers to use weather forecasting techniques in farming	Select crops such that their growing and harvesting times are not synchronised

Table 5. Classification of developed strategies.

Sl. no.	Aspect	Classification	Strategies	Factor				Descriptions (research areas)
				S	W	O	T	
1	Technological	Cold supply chain	S4O2 [‡] , S4O5, S2T1 (03 [§])	3**	–	2	1	Establish cold supply chain to store/distribute items and accordingly warehouses/delivery vehicles can be used
2		Distribution network	S1O4 ^{††} , S1O5, S2O3, S3O4, S4O3, S4O4, W2O4, W2O5, W3O2, W3O4, W3O5, W5O5, W2T2, W2T3 (14)	6	8	12	2	Restructure distribution network by considering various aspects like monitoring and controlling of AFSC activities, easy operational activities, optimum operation decisions, cross-docking, collection of produces from villages (farms), automation of AFSC activities, etc.
3		Transportation model	S3O5, W1O4, W1O5, W2O1, W2O2, W4O5 (06)	1	5	6	–	Re-design effective transportation model by incorporating smart logistics, pooling practices, collaborative transportation, etc.
4		Use of information technology (IT)	S1O2, S2O4, S3O2, W1O2, W4O1, W4O2, W4O4, S3T1, S3T3, W3T1, W4T1, W4T2 (12)	5	7	7	5	Use of IT at various stages of AFSC like information sharing, e-commerce, demand–supply integration, auctioning, weather forecasting, etc.
5	Social	Co-operation among farmers and collaboration between players	S5O3, S5O5, W1O1, W3O1, W3O3, W5T1 (06)	2	4	5	1	Develop model for co-operative marketing, collaboration with municipal corporations and integration of small farmers
6		Customer satisfaction	S1O1, S2O1, S4O1, S5O1, W5O1 (05)	4	1	5	–	Supply customized produces by considering seasonality into model and accordingly design feedback system for quality and services
7		Human resources development	S3O1, S5O2, W2O3, W5O2, S1T2, S3T2 (06)	4	2	4	2	Provide training to farmers for executing various AFSC activities
8	Agricultural	Farming methods	S2O2, S1T3, S2T2, S2T3, S4T1, S4T2, W1T1, W1T2, W1T3, W2T1, W4T3, W5T3 (12)	6	6	1	11	Farmers should focus on diversified farming, polyhouse farming, production of exotic vegetables and incorporate allied agriculture activities
9		Postharvest management	S1O3, S2O5, W5O3, W5O4 (04)	2	2	4	–	Establish small scale processing industry and provide latest postharvest technologies (sorting, packaging) to the farmers
10	Govern-mental	Recommendation to the government	S3O3, S5O4, W1O3, W4O3, S1T1, S4T3, S5T1, S5T2 S5T3, W3T2, W3T3, W5T2, (12)	7	5	4	8	The government should focus on minimum support price, infrastructure at re-distribution points, forming of special farming zone, environmental research and innovation. Also, web portals to help farmers, new modules/courses for postharvest management and incentivizing schemes for eco-friendly farmers can be started by the government to enhance agricultural productivity.

[‡] Strategy developed using strength 4 (table 1) and opportunity 2 (table 2).

[§] Number of strategies grouped in a classification.

**Frequency of strengths in a classified group.

†† Shortlisted strategies.

it will significantly improve the SC by solving the grass root problems of Indian ASFC.

6. Results

The twelve chosen strategies are highlighted in bold letters in tables 5 and 6. It is observed from table 6 that the twelve shortlisted strategies (15% of all) affect nineteen out of twenty-eight PMs (68% of all). Specifically, nine PMs not satisfied by the chosen strategies are shown in italics in table 6. It can be concluded from the table that the present shortlisted 12 strategies based on fulfilling maximum numbers of objectives satisfy all three dimensions of sustainability. Therefore, the chosen strategies are viable by achieving the proposed four objectives of the AFSC.

Table 6. Strategies with their satisfied objectives and performance measures.

	Column A: Objectives					Column B: Performance Measures																														
Strategy	a	b	c	d	T ^{max}	XA1	XA3	XB1	XC1	YC1	XC2	XC3	ZC2	ZB2	YA1	XB2	XB4	YC3	ZB4	ZC1	YB2	ZC3	XA2	XB3	ZB5	ZB1	ZB3	ZA2	XB5	YB1	ZA1	YB3	YC2	T		
S1O5	1	1		1	3	1	1	1	1	1	1	1																							7	
S1O1	1			1	2	1	1	1	1																										4	
S2O1		1		1	2	1	1			1	1																								4	
W3O2	1	1	1		3	1		1	1	1				1	1	1																			7	
W5O5	1	1	1		3	1		1	1				1				1	1	1																7	
S1O4	1	1	1		3	1		1		1			1			1				1	1														7	
S4O5					1	1				1	1																								3	
S3O4		1		1	2	1				1				1																					3	
S2O5		1			1	1				1			1																						3	
W5T2			1		1	1													1		1														3	
S3O5	1	1	1	1	4		1	1	1	1		1		1		1						1	1												9	
W4O1	1	1	1		3		1	1	1	1						1			1			1													7	
S2O3	1	1	1	1	4	1		1	1		1		1			1					1	1	1	1											9	
S3O2	1	1	1	1	4	1		1	1				1			1					1	1													7	
S2O4		1	1	1	3	1			1	1		1		1					1			1		1	1										8	
S1O2	1	1	1	1	4	1			1	1		1	1		1	1					1	1													8	
W3T3			1	1	2	1			1		1			1						1															4	
W3T1		1	1		2	1			1							1																			3	
W3T2		1		1	2	1			1											1															3	
S3T1		1			1	1				1												1		1											4	
S4O4			1	1	2	1					1															1	1									4
W2T3			1		1	1					1															1									3	
S3O1				1	1	1																	1				1								3	
W5O1				1	1	1																													1	
W2O2	1	1	1		3		1	1	1		1		1		1					1			1												8	
W2O1	1			1	2		1	1				1		1					1											1					6	
W4O2	1	1	1		3		1		1		1		1							1			1	1	1										7	
W5T1		1	1		2		1		1							1	1															1			6	
S4O3		1	1		2		1		1							1	1																		4	
W3O4		1	1		2		1		1											1			1												5	
W1O4			1		1		1						1		1	1														1					5	
W1O5			1		1		1						1		1	1																			4	
W2O5			1	1	2		1					1		1			1																		4	
W3O5		1	1		2		1										1																		4	
S5O5	1		1		2				1					1	1	1																1			6	
S5O3	1		1		2				1					1		1																			4	
W3O3	1		1		2				1						1	1																			4	
W5O4		1	1		2				1						1			1																	4	
S4O1	1		1		2				1																											2
S5O1	1		1		2				1																											2
S2T1		1			1					1	1						1	1																	4	
S4O2		1			1					1	1																									3

Table 6. continued

Strategy	a	b	c	d	T**	XA1	XA3	XB1	XC1	YC1	XC2	XC3	ZC2	ZB2	YA1	XB2	XB4	YC3	ZB4	ZC1	YB2	ZC3	XA2	XB3	ZB5	ZB1	ZB3	ZA2	XB5	YB1	ZA1	YB3	YC2	T
S1T1		1	1		2					1	1													1	1				1					5
W2O4		1	1		2					1			1			1						1												5
W4O4		1	1		2					1						1													1					5
W2T2		1	1		2					1													1											4
W1O1		1	1		2					1				1										1					1					4
W1O3		1	1		2					1					1	1	1																	4
W1O2		1	1		2					1									1			1		1										5
W4T1		1	1		2					1						1								1										3
W5O3		1	1		2					1							1		1								1							4
S1O3		1			1					1								1									1							3
S3O3		1			1					1								1									1							3
W1T3			1	1	2					1									1		1													3
W5T3			1	1	2					1									1					1	1									4
S4T1			1		1					1									1								1							3
W1T1			1	1	2					1									1															2
S5T1			1	1	2					1															1									2
W4O5		1		1	2						1											1	1						1					5
W3O1		1	1		2							1			1	1									1					1				5
W2O3			1		1												1	1							1									5
S3T2			1		1																				1									3
W4T2			1		1																				1					1				3
S2O2			1		1												1			1				1										3
S1T2			1		1													1						1										2
W5O2			1		1														1		1				1			1						4
S4T3			1		1																				1									2
S5O2			1		1																				1									3
S2T2			1	1	2																			1					1		1			4
W4O3			1		1																			1										2
S1T3			1		1																			1										2
S2T3			1		1																			1										2
S3T3			1		1																			1										2
W4T3			1		1																			1										2
S5O4			1		1																				1									3
W1T2			1		1																				1									4
S4T2			1		1																					1								2
W2T1			1		1																					1								2
S5T3			1		1																					1								1
S5T2				1	1																					1								2
T	18	41	64	20		10	17	17	16	35	14	7	16	12	11	31	9	3	29	6	4	12	10	20	17	7	3	4	8	3	2	2	0	
T Chosen	11	11	10	5		4	7	8	8	11	2	6	6	3	2	9	1	1	3	1	0	8	6	3	2	0	0	0	0	0	0	0	0	0

**Total of a row/column.

An objective achieved by the chosen strategies is totalled (column sum) and shown in the last row of table 6. It is observed that the number of shortlisted strategies achieving objectives (a), (b), (c) and (d) is 11, 11, 10 and 5, respectively. The chosen strategies focus mostly on the efficiency side rather than responsiveness side of the SC. Similarly, a PM covered by the chosen strategies is summed and it is calculated in three dimensions of sustainability. The shortlisted strategies contribute 59%, 25% and 16% in economic, social and environmental dimensions, respectively. Hence, the chosen strategies fit well in both the criteria (objectives and PMs) by solving the problems of Indian AFSC and they mainly improve the efficiency of the chain. Therefore, it can be said that the chosen strategies are the optimum strategies on the basis of fulfilling maximum number of objectives (row sum). Also, these strategies are also feasible strategies based on satisfying the maximum number of PMs. Thus, it is proved that the chosen strategies are the best candidate strategies on the basis of both the criteria, i.e., objectives (identified from real system) and PMs (modified in sustainability

dimensions from the available literature). Therefore, the shortlisted strategies are justified and recommended for designing sustainable Indian AFSC of the public or private organization to meet customer's demand in an efficient manner.

As discussed in sections 1 and 2, Indian AFSC is highly demanded to design sustainable distribution network for delivery of fresh items. Coincidentally, it is observed from table 5 (classification of strategies) that all the shortlisted strategies (in bold letters) belong to the classes of (1) distribution network, (2) transportation model and (3) use of IT-related strategies of the technological aspect. On the other side, none of the strategies in the finally selected strategies pertain to social, agricultural and governmental aspects. Hence, the chosen strategies (technological aspect) provide guidelines for designing sustainable Indian AFSC by targeting the efficiency of the chain.

Another important result can be discussed from the viewpoint of involvement of SWOT in the chosen strategies from table 5. Interestingly, threats are not defeated by any of the chosen strategies. The chosen strategies are seizing

Table 7. Modified performance measures in sustainability dimensions of AFSC.

Performance measures: economical dimension			
Sub-criteria of PM	Code	Benefits and improvements	Definition or measures
Quality	XA1	Quality of products	Determined by the taste, mealiness and aroma of the vegetable/fruit, combination of different attributes (colour, size and form, firmness, lack of blemishes and damage)
	XA2	Quality of services	Product delay, on-time delivery (%), number of stock outs, delivery reliability
	XA3	Customer satisfaction	The degree to which the customers are satisfied with the products or services, solution of registered complaints from customers about the product or service provided
Efficiency	XB1	Cost reduction by transportation	Reduce delivery cost by having efficient transportation model
	XB2	Cost reduction by pooling practice	Sharing transportation, warehousing and distribution facilities
	XB3	Cost reduction in production	Resources utilization for production, policy-oriented production, increase production quantity, combined costs of raw materials and labour in producing fresh items
	XB4	Productivity	Value-added productivity that increases the value that buyers receive from their purchases, postharvest management activities
	XB5	Transaction cost	The costs other than the price of raw material that are incurred in trading goods (e.g., searching cost, negotiation costs and enforcement costs)
Responsiveness	XC1	Lead time	Time interval in which product reaches from farmer to customer
	XC2	Varieties of products	Increase availability of varieties of products
	XC3	Delivery flexibility	The ability to change planned delivery dates/time, order flexibility (volume)
Performance measures: environmental dimension			
Emission	YA1	Green logistics/transportation	Reduction of CO ₂ emission (% or in tonnes), use of advanced technology, equipment and process to minimize environmental damage during operations
Natural resources utilization	YB1	Eco-friendly farming	Less use of pesticides, fertilizers and chemicals in production
	YB2	Less use of natural resources/unit output	Less use of energy, fuel, water and land per unit output
	YB3	Allied agricultural activities	The activities that are in some way related to agriculture, like animal husbandry, forestry, etc.
Waste and recycling	YC1	Waste reduction	Reduction of wastage in the distribution of produces
	YC2	Recycle/reuse	Recycle and reuse of packaging materials
	YC3	Reuse/recycle of food wastage	Reuse of food wastage for animal fodder, recycle wastage by producing compost

Proposed by authors
[13, 49]
[13, 49]
[13, 49]

Table 7. continued

Performance measures: social dimension			
Health and safety Employees (farmers)	ZA1	Product safety	Product does not exceed an acceptable level of chemical/organic produces
	ZA2	Accidents	Number of accidents that affect players, reduced probability of accidents during distribution
	ZB1	Employment	Jobs created by the system
	ZB2	Working conditions	Co-operation among farmers and collaboration between players
	ZB3	Training	Percentage of trained staff to use a new system (including driver, worker and farmer)
Working environment	ZB4	Profit	The positive gain from an investment or business operation after subtracting all expenses (return on investment) specially for farmers
	ZB5	Job security to players	Profit assurance to the players (farmers) by the system
	ZC1	Infrastructure at re-distribution points	Facilities at re-distribution points to enhance performance of the system
	ZC2	Standard operating conditions	Standard conditions required for transportation, storage and packaging of the products that are optimal for good quality
	ZC3	Traceability and visibility	Traceability is the ability to trace the history, application or location of a product using recorded identifications

available opportunities to improve the system with the help of internal factors strengths (S1–S3) and weaknesses (W2–W5). It is observed from table 1 that the nature of strengths (S4 and S5) may change from one time period to another (hence they are uncontrollable) whereas the weakness (W1) is an inherent property of the Indian agriculture system. Therefore, it is speculated that it may be a challenging task to formulate/choose viable strategies using these factors due to diversity and variability in Indian scenario.

7. Conclusion and future scope

The literature review points out that the current situation of Indian AFSC is highly unorganized and also faces many problems and an immediate attention is required to design SSC. Motivated from this, the agenda of this paper is to propose an action plan to target the problems of Indian AFSC. Therefore, the present study first examines Indian agriculture system followed by development strategies using TOWS matrix and ultimately shortlists some of the viable strategies for designing SSC. The complete process of development and shortlisting of strategies is summarized here.

Through literature survey the study identified internal factors (strengths, weaknesses) and external factors (opportunities, threats) as well as shortcomings of Indian agriculture system. Within a factor, several S/W/O/T focusing on the same feature are combined and converted into a small number of S/W/O/T, respectively. Eighty strategies are developed using various combinations of SWOT by brainstorming exercises. Similar types of strategies are classified into distinct groups, which can help in future research work. These classified groups are categorized into four different aspects (technological, social, agricultural and governmental) according to their existence in the group. Objectives are used as the shortlisting criterion such that they target the removal/mitigation of the shortcomings of Indian AFSC, which are (a)–(d). Objectives to be achieved by all the eighty formulated strategies are identified and the strategies satisfying three or more objectives are shortlisted as chosen strategies. Additionally, the shortlisting of strategies is verified using PMs of AFSC in sustainability dimension. The PMs satisfied by each of the strategies are determined and it is found that the chosen twelve strategies also satisfy the maximum number of PMs. The dominance of chosen strategies over others is further examined by applying rank order clustering.

To the best of our knowledge, this work is the first attempt in developing strategies for designing sustainable AFSC. Indian agriculture faces a lot of problems, particularly related to SC facet; therefore, this paper draws attention of research community towards forming sustainable agriculture. In this paper, we also proposed twelve viable strategies to improve the efficiency, which is an

urgent requirement of Indian AFSC. We hope that this work will provide a datum line for future research work in designing sustainable Indian AFSC. Limitation of this work lies in the fact that none of the proposed strategies could target social, agricultural and governmental aspects (table 5). These aspects can be further explored by the researchers working in each of these areas to identify efficient and feasible strategies. The remaining strategies related to Indian AFSC can be relooked by researchers to enhance the performance of chain in future research work.

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