Modelling a sustainable agri-food supply chain: a theoretic system construct

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Abstract: Stakeholders in an agri-food supply chain (AFSC) have responsibility to embrace sustainability as a yardstick to measure their business operations. System-based thinking for an AFSC is essential to harmonise interest of each parties while identifying and evaluating various critical success factors (CSFs) considering stakeholder's view in a sustainability perspective. This study examines relevant critical variables statistically tested for reliability and consistency for implementing system wide sustainability in AFSC. The total interpretative structural modelling (TISM) digraph is derived from the inter-relationship of the variables and the matrix multiplication applied to classification analysis (MICMAC) technique is used to priorities the CSFs based on the potency of their driving and dependence linkages. The developed model offers discussion, analysis and managerial implication in the light of stakeholder-oriented management within the overall paradigm of system sustainability. The study establishes that the government's role is the most important critical variable which conditions the whole system by offering guiding principles to all stakeholders for policy advancement and effective implementation. The study would help supply chain managers to avoid accumulating data that have little relevancy rather focus on the data built around critical variables only.

Keywords: system sustainability; critical success factor; CSF; stakeholder management; sustainable agri-food supply chain; total interpretative structural modelling; TISM; matrix multiplication applied to classification analysis; MICMAC.

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1 Introduction

The primary requirement to sustain an ever-increasing population is to meet their food demand. The need for producing more has accentuated concern for food quality and unsustainable depletion of natural resources. The traditional method of managing an agri-food supply chain (AFSC) is no longer effective and the solution lies in integrating the concept of sustainability with that of supply chain management (Touboulic and Walker, 2015). Various players in the agriculture system, e.g., raw material providers, producers, food processors, storage and distributors, consumers and waste managers play a crucial role in ensuring a sustainable AFSC. Bulk of the studies for sustainable AFSC have focused on green or organic farming issues (Pugliese, 2001) which already has augmented the awareness for importance of production sustainability (Bhaskaran et al., 2006). However, incorporating sustainable method of production constitutes only a part of the sustainable agriculture system and one must systematically analyse the upstream and downstream stages of an AFSC for achieving social, economic and environmental equilibrium as a step towards long-term sustainability (Ahi and Searcy, 2013; Govindan, 2018; Leppelt et al., 2013). The sustainability triad, viz., economic viability, social progress and environmental preservation are the mainstay of AFSC and remain in constant interaction with each other (Fritz and Schiefer, 2008). Incorporation of technology not only brings cohesiveness in the whole supply chain but also advances the pace of interaction between the sustainability triad and therefore is an important sustainability enabler (Seuring and Müller, 2008). Rai et al. (2006) and Subramani (2004) in their study of impact of information and communications technology (ICT) on supply chain deduced that ICT significantly enhances supply chain operational performance resulting in higher revenue growth. However, the challenge of accommodating varied interests of different stakeholders and their disparate approaches to strive for profit maximisation acts as biggest impediment in transformation of traditional AFSC into a sustainable one (Gold and Schleper, 2017).

Due to the measures initiated by the United Nations Environment Programme (UNEP), government policies and research studies, there is growing awareness among the consumers for the need of an effective oversight for sustainability implementation in the food processing operations. The number of consumers who wish to spend more on sustainable and eco-friendly products is growing (Zhou et al., 2016). This has prompted, though at a small level, proactive declaration by some AFSC that they employ sustainable methods to gain and retain consumer trust (Weng et al., 2015). However, the growing consumer demand for sustainable food has also led to proliferation in green certification, labels and marketing. This invariably requires effective legal regulation that verifies the genuineness of sustainable food production (Brach et al., 2017).

1.1 Research gap and objectives

It can be arguably stated that sustainability as a goal is a dynamic concept which cannot be merely defined by a certain set of agricultural practices (Tabasz, 1976). However, there are acceptable set of enablers which could facilitate implementation of sustainability goal in a supply chain. Few enablers identified are governmental regulation, managerial practices, customer awareness and response, etc. which have a significant influence on sustainability (Glover et al., 2014). A whole lot of research is devoted to identifying factors critical to achieving sustainability in AFSC (Akenji and Bengtsson, 2014; Beske et al., 2014; Chkanikova and Mont, 2015; Luthra et al., 2018; Raut et al., 2018). However, in the examination of the literatures, it is found that void exists in identifying and analysing the enablers from a system's perspective. Previous studies took a static view and largely ignored that the criticality associated with a critical success factor (CSF) may vary depending upon the changes in its environmental setting. A stakeholder in a supply chain only knows about the other stakeholders positioned adjacent to it. Only by seeing the stakeholders in relation to the complete supply chain setup (i.e., system thinking) one can hope to understand how the mechanism of sustainability could work. No study has adopted a hybrid model of integrating system sustainability and stakeholder theories with TISM and MICMAC methodologies. This study tries to bridge these gaps. Like any system, a supply chain system can be broken down into subsystems, and each subsystem into multi-step processes. Breaking down the system enables dealing with manageable pieces to identify and remove the impediments in the sustainability goal. Making use of TISM, this work intends to determine interrelatedness among the CSFs and present a model that would illustrate which all factors are crucial for sustainability. This paper has attempted to use TISM and MICMAC as a methodology to give a theoretic system construct for sustainability adoption in the AFSC system. Research objectives of the paper are:

a To identify CSFs for a sustainable AFSC system by review of relevant literature and seeking expert advice.

b To establish relative importance, correlation and interdependence among identified factors by using total interpretative structural modelling (TISM) technique with expert opinion (industry and academic).

c To analyse the contextual relationship through driving and dependence power of different CSFs and cluster it by using matrix multiplication applied to classification analysis (MICMAC).

This paper is organised in four parts. The introduction builds the contours of the research work and lays emphasis on the sustainability aspect of the AFSC. Based upon the validity and reliability analysis of the response data received from the experts and relevant literature material, Section 2 of the work, identifies and describes the CSFs for a sustainable AFSC. Section 2 also explains the relevant theory apropos the study. It is followed by Section 3 which contains description of sequence of steps adopted in TISM and MICMAC methodology. Lastly, Section 4–6 presents analysis of discussions in the form of result, managerial implication and conclusion.

2 Literature review

The underlying concepts which are core to this study are given as under:

2.1 Sustainable supply chain management

The process of operating a supply chain in conditions restrained by the economic, social and environmental considerations in a long-term perspective brings sustainability aspect to the supply chain (Ashby et al., 2012; Stephens et al., 2018; Touboulic and Walker, 2015). Managing a sustainable supply chain implies maintaining economic viability without adversely impacting the social and environmental systems (Pagell and Shevchenko, 2014). However, it must be asserted that attaining sustainability in a supply chain is not an event but a protracted continuous improvement process (Silvestre, 2015).

2.2 Stakeholder theory

Several authors have built upon and developed their own interpretation of Stakeholder Theory since it was introduced by Freeman (1984) wherein he referred stakeholder as a key player that can affect or get affected by the organisational activity. The stakeholder theory emphasises that a manager should advance interest of all stakeholders rather than only shareholders (Simcic Brønn and Brønn, 2003). A stakeholder perspective enables a firm to incorporate proactive ways to change its business operation in relation to the changes in its surroundings (De Bussy et al., 2003). Stakeholder in a business operation differ from company to company and situation to situation. Given the diversity of stakeholders, and their competing and usually contradictory interests, decision makers need to evaluate relative importance of the stakeholders' claim and prioritise them accordingly. With sustainability aspect being increasingly incorporated as part of the corporate social responsibility and in all business operations, it is necessary that stakeholders' awareness, control and commitment toward sustainability development must be handled as part of the management strategy (El Bilali et al., 2019). This paper attempts to utilise stakeholder framework and its theoretical propositions to model the AFSC for system sustainability.

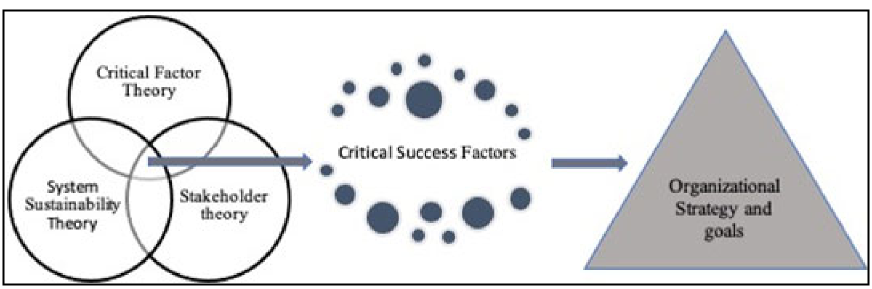
2.3 System sustainability theory

Players in a supply chain tend to operate in self-interest and adopt disjointed and piecemeal approach. Considering the organisation as a system, its functions and nature are governed by various subsystems which may have economic, social and environmental considerations (Roth, 2016; Cabezas et al., 2005). Only when these myriad subsystems are focussed and streamlined to work together for the organisational purpose can bring system stability and efficiency. Such a system-based approach recognises that activity/progress at one node in a supply chain could either enhance or undermine events at other nodes. The system sustainability approach allows companies to better adapt to their environments and accordingly respond to different realities they face (Plaza-Úbeda et al., 2019). A whole-system perspective enables better articulation/formulation of economic and political-policy decisions for a sustainable paradigm (Pappas, 2012). A sustainable system relies on effective feedback for stabilisation that helps in easy identification and removal of problems symptomatic of flaws in the supply chain system.

2.4 CSF theory

A CSF defines key performance indices indispensable for accomplishment of organisation's vision and mission. A strong and sustained result in fields indicated by CSFs guarantees operational success for the organisation. Therefore, the CSFs must appertain to the supply chain's strategic drivers in a given external environment setting (Amberg et al., 2005; Esteves de Souza, 2004). The application of CSF analysis can reduce organisation ambiguity as it provides decision makers with more dependent, dynamic and independently verifiable set of key performance areas in reference to the operating environment of the organisation. However, identifying CSFs require not only exploring relevant literatures but also detailed consultation with professional and subject matter experts from academia and industry (Katayama and Bennett, 1999; Power et al., 2001).

Figure 1 Contours of the literature review (see online version for colours)



2.5 Identification of CSFs

Figure 1 depicts the theoretical motivation in the identification of CSFs and their role in achieving organisational goals. While carrying out an exhaustive study of the relevant literature available on the agri-supply chain and sustainability topics, an emphasis was given to incorporate recent studies done by the researchers on the subject. Several CSFs identified are:

2.5.1 Integration of national agriculture market

Due to diverse agro-climatic conditions, the agriculture produce differs in nature, quality and quantity across regions. A farmer requires easy market access wherein the prices of his produce can be negotiated. Poor infrastructure and lack of information dissemination act as barriers for better market integration of agricultural commodities (Praveen and Inbasekar, 2015). Factors that affect market integration are

1 market infrastructure like transportation, communication, etc.
2 government's trade and credit policy
3 inter-regional imbalances like surplus and deficit production
4 supply shock, e.g., drought and flood (Goletti et al., 1995).

Integrating agri-markets counterpoises the disparity of food produce in the regions and safeguards food security (Katengeza et al., 2013). Use of ICT can enable establishment of a centralised marketplace that would allow farmers to list their produce, receive offers and negotiate best prices for their commodities. It would facilitate farmers to connect to different mandis and get access to real-time price information of agri-commodities, allowing money transfer through e-payment that contributes to market efficiency.

2.5.2 Coordination and collaboration in AFSC

Food loss and resource wastage tend to increase sharply in absence of effective AFSC coordination (Govindan, 2018). Collaboration among stakeholders is recognised as the prime mover to increase business performance and sustainability (Doukidis et al., 2007; Ramanathan et al., 2014). However, it is difficult to manage because of challenges like with whom and when to collaborate, for what reasons and how to implement collaboration (Barratt, 2004). Likewise, coordination requires coherent and interoperable channel of communication to enhance timely response for balancing demand and supply. Coordination means interaction among the supply chain actors to develop risk strategies, cost reduction, safety and quality improvement (Handayati et al., 2015; Kuwornu et al., 2009; Sutopo and Hisjam, 2012), whereas collaboration leads to competitiveness of entire AFSC system (Dunne, 2008). Implementing collaboration among stakeholders of a supply chain enables improved understanding of resource sharing needs that helps in better coordinating responses during the time of crisis (Gómez and Ricketts, 2013).

2.5.3 Risk management

While it is difficult to eliminate risk associated with a supply chain, concerted efforts should be made towards management of risk (Ho et al., 2015). Risk management is a continuous process that helps in arriving at an optimal path during the time of uncertainty that would help in striking a balance between the three pillars of sustainability (Liu et al., 2004). Proactive approach to risk management remedies risk impact and assists in modelling a sustainable AFSC system (Giannakis and Papadopoulos, 2016; Rostamzadeh et al., 2018). Researchers have argued that sustainability implementation in itself is a risk management strategy as it enhances resilience by adopting and streamlining internal processes in proportionate with changes in external conditions (Ahi and Searcy, 2013; Kaur and Bhardwaj, 2019; Kiron et al., 2015; Kucuk Yilmaz and Flouris, 2010). Agricultural procedures like eco-sourcing, eco-packaging, eco-processing and eco-waste-management can also help in the management of risk. Integrating sustainable practices with upstream and downstream actors can significantly enhance the performance and effectiveness of AFSC by better utilisation of resources while mitigating the risk involved in the chain (Carter and Rogers, 2008).

2.5.4 Trust among partners

Trust brings synergy to any supply chain as then all stakeholders shall operate on a belief system that would enable them to take actions benefiting all partners and prevent them from actions that is likely to result in bad outcome (Schoorman et al., 2007; Uca et al., 2017). A high level of trust enables open communication and enhances risk taking ability among partners in a buyer-supplier relationship (Corsten and Kumar, 2005; Kwon and Suh, 2005). Conversely, a functional sustainable system reinforces trust and enhances loyalty among its partners and customers. Trust removes small barriers and generates confidence among partners that their long-term vision is sustainable (Saxena et al., 1990).

2.5.5 Storage and processing facilities

Efficient agri-product storage and processing facility not only help in sustaining the product quality for a longer duration but also significantly contribute in reducing food wastage (Accorsi et al., 2017; Negi and Anand, 2015). Sustainable processing lays emphasis on food quality and safety standards, nutritional adequacy, waste recycling, process standardisation, cost reduction and customer satisfaction (Lazaridesa, 2011).

2.5.6 Logistics network and capabilities

Logistics involves management of flow of materials throughout the network chain that is optimised via data-driven planning (Mangina and Vlachos, 2005; Manzini et al., 2014). Designing an integrated logistic network for a sustainable AFSC involves reducing distribution cost while ensuring timely delivery (Amorim and Almada-Lobo, 2014), minimisation of the greenhouse gas emissions (Validi et al., 2014), ensuring food safety, security and quality while minimising wastage (Akkerman et al., 2010). Efficiently designed logistic network not only reduces carbon footprint but also result in cost saving and faster delivery of perishable and non-perishable goods (Savino et al., 2015).

2.5.7 Government regulations and policies

Government role is fundamental in defining sustainability goals for AFSCs within the economy (Luthra et al., 2015; Tseng et al., 2013). Positive state intervention to provide assistance and regulations acts as stimulus for infrastructure building in areas of transportation, storage, renewable and reliable energy. Moreover, the state's role is pivotal in formulating market policy, organising training programs for farmers, building adequate quality control and testing centres, devising pricing and taxation policy, incentivising organisations for adopting risk management, etc. in order to enhance capacity of domestic producers to compete in the international market (Caniato et al., 2012; Mitra and Datta, 2014; Wu et al., 2012). In developing world, where agriculture sector has significant share in country's GDP and employs large section of the population, the success and failure of government is measured by the performance of the agriculture sector (Raju, 2014) and hence the government role is all encompassing in various stages of the AFSC (Naik and Suresh, 2018).

2.5.8 ICT infrastructure

Inadequate adoption and sketchy implementation of technology driven agri-solutions hindered the growth of agri-food sector in India from realising its true potential (Rao, 2007). Effecting ICT contrivances in AFSC for data exchange and information sharing among chain partners on demand-supply mismatch, wastages, stocks and storages, etc. in real-time is intrinsic to sustainability adoption (Grunfeld and Houghton, 2013). However, there is glaring gap between modern technology being developed at the agri-research institutions and its wide acceptance and implementation by the small-scale farmers (Kroma, 2003). ICT training for cost-effective and sustainability practices ought to be adequately explained to farmers for encouraging results.

2.5.9 Food quality

Quality of the food product is one of the top desirability factors for it to be sold in the marketplace (Narrod et al., 2009); which encompasses quality of raw materials, internal and external levels of processing, product standard and safety issues (Fernandes et al., 2009). The quality of the food and standard of production employed largely determine the willingness of the customer to pay for the product. As consumers are becoming more aware, they tend to reject poor quality food products resulting in wastage. The quality of the end product depends on the quality of input and hence maintaining quality throughout the AFSC is an important CSF for a sustainable supply chain.

2.5.10 Visibility and traceability

An efficient traceability system provides correct, complete and consistent information about the product flow to all the stakeholders across the AFSC (Regattieri et al., 2007). An integrated approach towards the management of tracking and tracing of products in AFSC ensures maintenance of food quality and security as it leads to detection of fraudulent activities like adulteration and contamination thus enabling less wastage, reduced recall cost and timely deliveries (Bosona and Gebresenbet, 2013).

2.5.11 Customer awareness and satisfaction

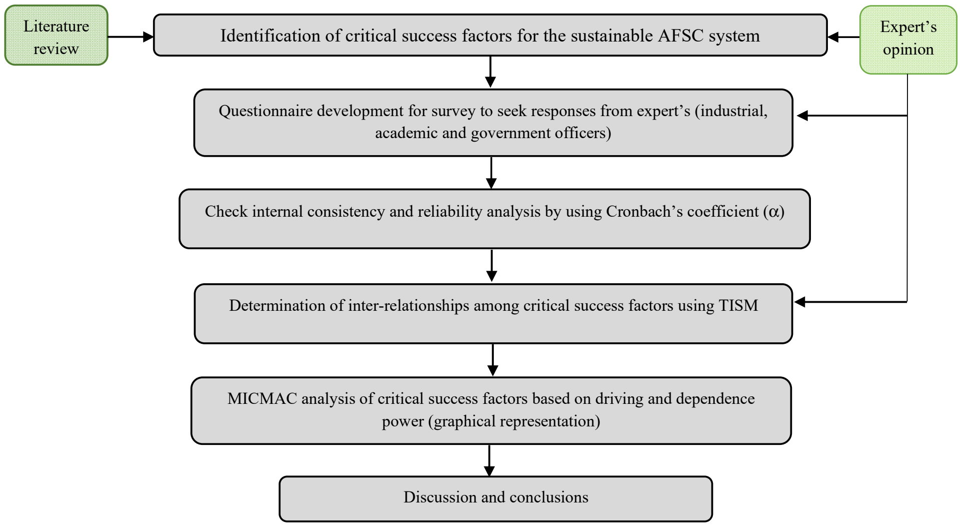
As awareness among consumers increases, they tend to enquire more about the product information which is not just limited to assessing its quality but also regarding processing methods and their ecological effect (Kinnear et al., 1974). Consumers tend to practice this comparison to build brand affiliation while providing effective feedback systems. Customer satisfaction and loyalty ensure continuity of a business, now and in the future. The purpose of a sustainable AFSC is to satisfy consumers by providing cost-effective quality product at the right place and time.

3 Research methodology

3.1 Framework of research

The schematic diagram of entire research flow is depicted in Figure 2.

Figure 2 Flow diagram for proposed research work (see online version for colours)



3.2 Reliability test using Cronbach's coefficient (α) and Pearson's correlation test using SPSS

Examining literature and undertaking questionnaire-based survey to obtain opinions from the industry experts, academic and subject specialists, government and private professionals; a total of 11 CSFs pertaining to AFSC were identified in this research work that are germane to imbibing system-wide-sustainability. The standard and merit of the experts, not their number, is core to the decision-making (Ocampo and Promentilla, 2016) and this was taken into account while undertaking the questionnaire-based survey. The academicians and industry experts were carefully chosen who have necessary experience in AFSC management and hold higher position in their respective fields. The qualification criteria for the experts are indicated in Table 1.

Table 1 Qualification of expert decision makers

Experts	*Qualification criteria*	*No. of experts*
Government agencies	Experience: At least ten plus years of working experience in AFSC management and knowledge about sustainability in agri-food domain.	10
Industry experts	Experience: At least ten plus years of working experience in AFSC and must be in the top management position. Must have knowledge about sustainability in agri-food domain.	15
Academic experts	Educational qualification: Master or doctoral degree in relevant stream. Experience: At least five plus years of research and teaching experience in AFSC management and must have knowledge about sustainability in agri-food domain.	10

Table 2 Correlation coefficient of CSFs

	Correlations										
	CF11	*CF10*	*CF9*	*CF8*	*CF7*	*CF6*	*CF5*	*CF4*	*CF3*	*CF2*	*CF1*
CF1	0.431**	–0.021	–0.054	0.347*	0.502**	0.361*	0.412*	0.425**	0.013	0.437**	
CF2	0.127	0.238	0.307	0.321	0.174	0.240	0.353*	0.220	0.060		
CF3	0.081	0.431**	0.313	0.197	0.245	0.044	0.317	0.015			
CF4	0.279	–0.038	–0.121	0.255	0.247	0.302	0.301				
CF5	0.405*	0.298	0.317	0.375*	0.600**	0.146					
CF6	0.411*	0.162	0.201	0.607**	0.037						
CF7	0.523**	0.161	0.077	0.120							
CF8	0.213	0.310	0.235								
CF9	–0.068	0.772**									
CF10	0.018										
CF11											

Notes: **correlation is significant at the 0.01 level (2-tailed).
*correlation is significant at the 0.05 level (2-tailed).

In the survey, the expert panel members participated to quantify the relevancy of the identified CSFs based on quintuple Likert psychometric scale where 1 indicates 'not relevant' and 5 indicates 'highly relevant'. The Cronbach's coefficient is used to assess the reliability and measure the strength of internal consistency of the response dataset obtained from the expert opinion survey. The acceptable range for Cronbach's coefficient (α) is: ≥0.9 – excellent; ≥0.8 – good; ≥0.7 – acceptable; ≥0.6 – questionable; ≥0.5 – poor; and >0.5 – unacceptable (Saxena et al., 1990). For the sample size of 35 considered in this study, the value of Cronbach's coefficient (α) is 0.779 which is well within the acceptable limit. Additionally, Pearson's bivariate two-tailed correlation test was done to check whether there is any multi-collinearity among the identified CSFs. Table 2 depicts the result of correlation test which indicates there is no multi-collinearity. The result of Cronbach's coefficient (α) and correlation test are obtained by using SPSS 20 version software.

3.3 TISM methodology

In the year 1978, Warfield gave a convincing methodology for analysing complex issues called interpretive structural modelling (ISM). It helped to establish conceptual association among variables (Charan et al., 2008). However, the inherent deficiency in ISM is that it does not clarifies the way in which directed relationship among the variables is conceptualised (Sushil, 2012). The TISM method is further development of the ISM methodology wherein the relationships are construed in the light of interpretive matrix (Dubey et al., 2017; Jena et al., 2017) allowing interpretation of direct relations as well as transitive relations (Sandbhor and Botre, 2014). Today, TISM is well established and widely accepted as a decision-making tool by researchers.

3.3.1 Steps in TISM

The identification of CSFs pertinent to developing a sustainable AFSC forms the first step of the TISM ladder. In this research, 11 CSFs are identified. The next step is to identify contextually relevant relationship among various CSFs and interpret the relationship among the 11 CSFs. This interpretation is used to develop a structural self-interaction matrix (SSIM) in which prominent influential relations are assigned yes (Y) and least influential relations are assigned no (N). This matrix is converted into a binary matrix (0 or 1) representing relations to obtain an initial reachability matrix as shown in Table 3. If attribute A influences another attribute B which in turn influences attribute C, then there exists a transitive relation between A and C. All the transitive relations are embedded in the initial reachability matrix to form the final reachability matrix as shown in Table 4. This is followed by the partitioning the attributes level-wise to clearly identify their position in the hierarchy based on antecedents, reachability and intersection. The process is iterated until an attribute level is defined as shown in Table 5. A digraph is drawn by arranging each factor as per the level obtained in level partitioning. An interpretive matrix is developed which highlights significant relationships among the factors as shown in Appendix. The digraph is now plotted using the interpretive matrix representing most influential relations arranged level-wise to give the TISM structural model as shown in Figure 3.

Table 3 Initial reachability matrix

	Critical success factors	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1	Integration of national agriculture market (CF1)	1	1	1	1	1	1	0	1	1	1	1
2	Coordination and collaboration (CF2)	0	1	1	0	0	1	0	0	1	0	1
3	Risk management (CF3)	0	1	1	0	0	1	0	0	1	0	1
4	Trust among the partners (CF4)	0	1	1	1	0	0	0	0	1	1	1
5	Storage and processing facilities (CF5)	0	1	0	0	1	1	0	0	1	1	1
6	Logistics network (CF6)	0	1	1	0	0	1	0	0	1	0	1
7	Government regulations and policies (CF7)	1	1	1	1	1	1	1	1	1	1	1
8	ICT infrastructure (CF8)	0	1	1	1	1	1	0	1	1	1	1
9	Food quality (CF9)	0	0	0	0	0	0	0	0	1	0	1
10	Visibility and traceability (CF10)	0	1	1	1	0	1	0	0	0	1	1
11	Customer satisfaction (CF11)	0	0	0	0	0	0	0	0	0	0	1

Figure 3 System model for CSFs for a sustainable AFSC (see online version for colours)

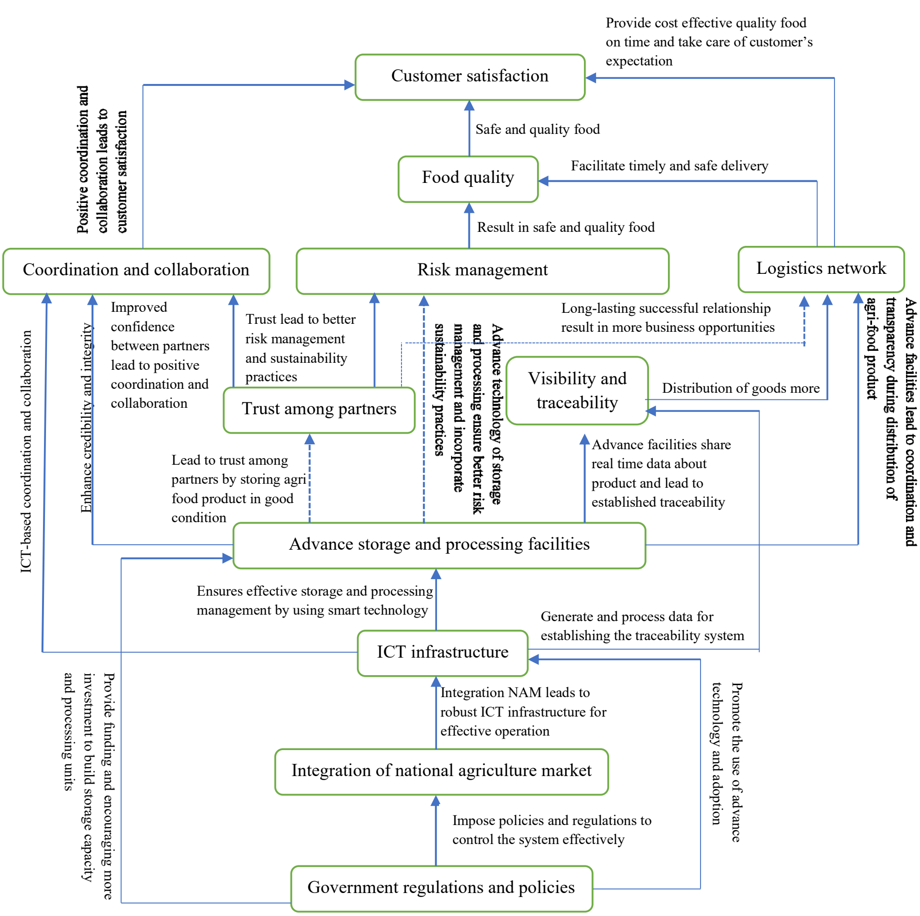


Table 4 Final reachability matrix

	Critical success factors	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1	Integration of national agriculture market (CF1)	1	1	1	1	1	1	0	1	1	1	1
2	Coordination and collaboration (CF2)	0	1	1	0	0	1	0	0	1	0	1
3	Risk management (CF3)	0	1	1	0	0	1	0	0	1	0	1
4	Trust among the partners (CF4)	0	1	1	1	0	*1*	0	0	1	1	1
5	Storage and processing facilities (CF5)	0	1	*1*	*1*	1	1	0	0	1	1	1
6	Logistics network (CF6)	0	1	1	0	0	1	0	0	1	0	1
7	Government regulations and policies (CF7)	1	1	1	1	1	1	1	1	1	1	1
8	ICT infrastructure (CF8)	0	1	1	1	1	1	0	1	1	1	1
9	Food quality (CF9)	0	0	0	0	0	0	0	0	1	0	1
10	Visibility and traceability (CF10)	0	1	1	1	0	1	0	0	0	1	1
11	Customer satisfaction (CF11)	0	0	0	0	0	0	0	0	0	0	1

Note: Italic 1 indicates transitivity link.

Table 5 Iterations for level partitioning

	Critical success factors	*Reachability*	*Antecedent*	*Intersection set*	*Level*
1	Integration of national agriculture market (CF1)	1, 2, 3, 4, 5, 6, 8, 9, 10, 11	1, 7	1	VII
2	Coordination and collaboration (CF2)	2, 3, 6, 9, 11	1, 2, 3, 4, 5, 6, 7, 8, 10	2, 3, 6	III
3	Risk management (CF3)	2, 3, 6, 9, 11	1, 2, 3, 4, 5, 6, 7, 8, 10	2, 3, 6	III
4	Trust among the partners (CF4)	2, 3, 4, 6, 9, 10, 11	1, 4, 5, 7, 8, 10	4, 10	IV
5	Storage and processing facilities (CF5)	2, 3, 4, 5, 6, 9, 10, 11	1, 5, 7, 8	5	V
6	Logistics network (CF6)	2, 3, 6, 9, 11	1, 2, 3, 4, 5, 6, 7, 8, 10	2, 3, 6	III
7	Government regulations and policies (CF7)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	7	7	VIII
8	ICT infrastructure (CF8)	2, 3, 4, 5, 6, 8, 9, 10, 11	1, 7, 8	8	VI
9	Food quality (CF9)	9, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	9	II
10	Visibility and traceability (CF10)	2, 3, 4, 6, 9, 10, 11	1, 4, 5, 7, 8, 10	4, 10	IV
11	Customer satisfaction (CF11)	11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	11	I

Table 6 Driving and dependence power using final reachability matrix

	Critical success factors	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*Driving power*
1	Integration of national agriculture market (CF1)	1	1	1	1	1	1	0	1	1	1	1	10
2	Coordination and Collaboration (CF2)	0	1	1	0	0	1	0	0	1	0	1	5
3	Risk management (CF3)	0	1	1	0	0	1	0	0	1	0	1	5
4	Trust among the partners (CF4)	0	1	1	1	0	*1*	0	0	1	1	1	7
5	Storage and processing facilities (CF5)	0	1	*1*	*1*	1	1	0	0	1	1	1	8
6	Logistics network (CF6)	0	1	1	0	0	1	0	0	1	0	1	5
7	Government regulations and policies (CF7)	1	1	1	1	1	1	1	1	1	1	1	11
8	ICT infrastructure (CF8)	0	1	1	1	1	1	0	1	1	1	1	9
9	Food quality (CF9)	0	0	0	0	0	0	0	0	1	0	1	2
10	Visibility and traceability (CF10)	0	1	1	1	0	1	0	0	0	1	1	7
11	Customer satisfaction (CF11)	0	0	0	0	0	0	0	0	0	0	1	1
Dependence		2	9	9	6	4	9	1	3	10	6	11	70/70

3.4 The MICMAC principle

The principle of multiplication of the matrices to identify indirect inter-relationship between variables forms the basis of MICMAC analysis. The indirect relationship existing between two variables can be revealed when the matrix is squared, e.g., if a matrix gets multiplied n times, the rank and position of the n^{th} order, between the variables can be estimated. Repeating this process, a pecking order of the variables can be concluded which are connected through indirect relationship. This indirect relationship gets stabilised after a stage when recurring multiplication of matrices give stable order of variables. This hierarchy is the MICMAC classification (Saxena et al., 1990). The MICMAC principle can be applied to CSFs to classify them in four classes based on their mutual influence as shown in Table 7 (Darbari et al., 2018). The four clusters are namely, autonomous, dependent, linkage and driving factors as shown in Figure 4.

- Autonomous factors (class I) indicate weak mutual influence. These factors are largely independent in the system.
- Dependent factors (class II) indicate weak driving power and strong dependence power. These variables get influenced but do not influence other factors.
- Linkage factors (class III) indicate strong driving power and strong dependence power. They act as a connecting link among other variables in the system.
- Driving factors (class VI) indicate strong driving power and weak dependence power. Factors under this class drive other variables and do not get influenced by other variables in the system.

Table 7 MICMAC analysis cluster

Class	*Critical success factors*
Autonomous factors	No factor
Dependent factors	Coordination and collaboration (CF2); risk management (CF3); logistics network and capabilities (CF6); food quality (CF9); customer satisfaction (CF11)
Linkage factors	Trust among the partners (CF4); visibility and traceability (CF10)
Driving factors	Integration of national agriculture market (CF1); storage and processing facilities (CF5); government policy and regulation (CF7); ICT Infrastructure and capabilities (CF8)

Figure 4 MICMAC analysis (see online version for colours)

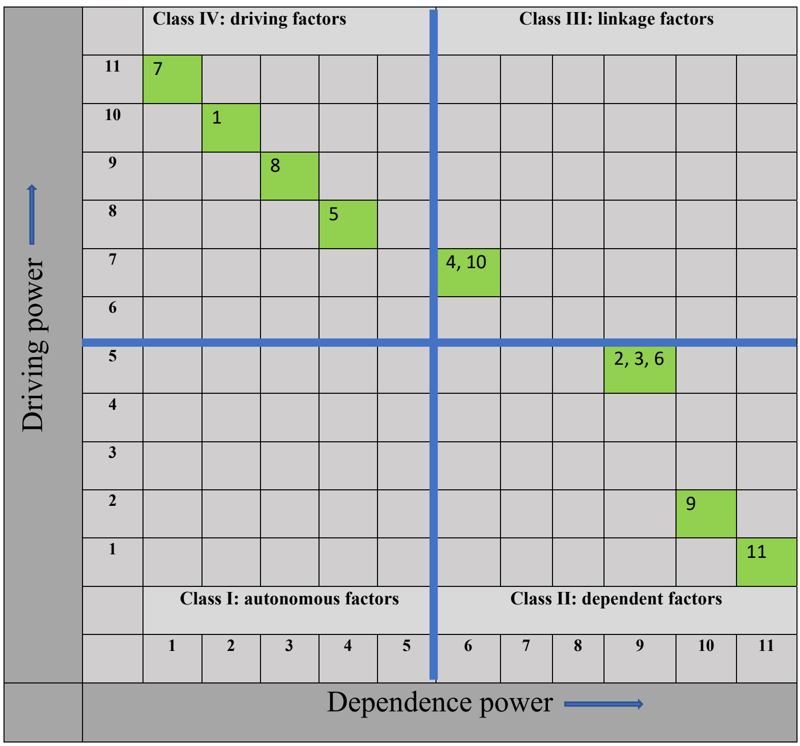


Table 8 MICMAC ranking

CSF's no.	*CF7*	*CF1*	*CF8*	*CF5*	*CF10*	*CF4*	*CF6*	*CF3*	*CF2*	*CF9*	*CF11*
Driving power (A)	11	10	9	8	7	7	5	5	5	2	1
Dependence power (B)	1	2	3	4	6	6	9	9	9	10	11
A/B	11.00	5.00	3.00	2.00	1.167	1.167	0.556	0.556	0.556	0.200	0.091
MICMAC ranking	1	2	3	4	5	5	6	6	6	7	8

4 Result and discussion

The TISM-based inter-relationship model of CSFs for a system-wide AFSC sustainability developed from the final reachability matrix (Table 4) and level partitions (Table 5) is shown in Figure 3. The driving as well as dependence power of factors form the basis for establishment of the direction of relationship as depicted in the digraph.

4.1 Interpreting TISM digraph

The 11 CSFs are partitioned into eight levels as depicted in Table 5. It is pertinent to mention that in the TISM digraph presented in Figure 3, the bottom level CSFs exert influence on factors above them and play dominant role than the higher placed factors to achieve the intended objective. The government regulation and policies (CF7), a level VIII factor, is of paramount importance and drives other factors considered in the study. Apart from tackling issues of subsidies and market access to farmers, the government role is crucial in implementing agriculture reforms and formulating policies to attract private sector investment. In the wake of limited private sector investment, government intervention is pivotal in propelling technology driven innovation and providing suitable infrastructure for the processing, transportation, storage and distribution of food products as per sustainability requirement of AFSC (El Bilali et al., 2019). CF7 influences level VII factor, i.e., integration of national agriculture markets (CF1). Increasing market integration implies better market efficiency and competitiveness. It also leads to more efficient allocation of resources and products across the region, a necessary condition for achieving sustainable agriculture development. Likewise, availability of robust ICT infrastructure (CF8), a level VI factor, influences factors above it in the hierarchy like storage and processing facility (CF5), visibility and traceability (CF10), trust among partners (CF4), effective coordination and collaboration (CF2), efficient logistics network (CF6) and management of risk (CF3). ICT tools can help to achieve system-wide agri-food sustainability by augmenting resource productivity, reducing inefficiencies, lowering management costs and enhancing coordination along the chain that have positive environmental, social and economic impacts (Katayama and Bennett, 1999; Power et al., 2001). Level III contain three factors, viz., coordination and collaboration (CF2), logistics network (CF6) and management of risk (CF3). All these factors interact with each other and closely related with a feedback loop. Positive development in one has a constructive and affirmative impact on the other two. Sustainable practices and efficient waste management not only help in management of risk but also improve food quality (CF9) leading to better customer satisfaction (CF11). Likewise, better logistic network and coordination among partners ensure timely delivery of product at minimum cost while safeguarding its quality, thus guaranteeing better customer satisfaction (CF11). The realisation of the objectives at the top in the TISM digraph can be achieved only with improved performance of the factors at the bottom (Patri and Suresh, 2017). The focus for improvement in overall performance of the AFSC should initiate from bottom levels for the goal of system wide sustainability to come to fruition.

4.2 Interpretation of MICMAC analysis

The inter-relationship among CSFs forms the basis of classification for the driving or dependent linkages as depicted in Figure 3. No CSF is an autonomous factor as none of the them lies in class I indicating all identified CSFs are essential to sustainability. The MICMAC ranking of all CSFs indicating the relative importance of level of factors and their influencing level is provided in Table 8. The analysis shows that government policy and regulation (CF7) is the most essential factor impacting system sustainability development for the AFSC. Factors like integration of national agriculture market (CF1), ICT infrastructure (CF6) and storage and processing facilities (CF5) are strong drivers for system sustainability and directly contribute for its effective implementation. Middle level factors like visibility and traceability (CF10) and trust among the partners (CF4) have considerable driving and low dependence power. They act as linkage factors and need to be monitored carefully as any change in activity linked with these factors have repercussions on other variables. The inbuilt feedback mechanism would support and assist in amplifying the initial pulse. The factors like coordination and collaboration (CF2), risk management (CF3) and logistic network (CF6) have low driving and medium dependence but improvement in these variables bring cohesiveness in overall system. Factors like food quality (CF9) and customer satisfaction (CF11) are the weakest drivers and considered as mainly dependent variables. This analysis could act as the guiding principle in grading the CSFs for allotment of the resources in commensurate with their ranking for effecting the change process of system sustainability development.

4.3 Stakeholder influence on system sustainability

In a business world, economic considerations far exceeds the social and environmental determinants. Government regulation remains springboard for facilitating stakeholders to embrace sustainability in their operations. Government bodies are best suited to comprehensively formulate sustainability standards and regulations, lack of which certainly impede sustainability integration (Delai and Takahashi, 2011). The policy framework should be modelled and developed to integrate sustainability in the decision making for all stakeholders at all levels. Though regulations and conditions may not guarantee sustainability compliance, but still they would offer guiding principles for all stakeholders for policy advancement and effective implementation (Grant et al., 2017).

4.4 Managerial implication

The research provides decision makers with necessary theoretical study to delve deeper into the implementation part of the system sustainability strategy for the AFSC. Apart from describing which critical factors should invite managerial attention for closer scrutiny, the enumeration of CSFs and their relative importance using MICMAC analysis and ranking cautions a manager from getting stuck in the trap of accumulating data that have little relevancy, instead focus on the data built around critical variables only, thus saving time and money. The research suggests that some critical variables are temporal and external environment specific therefore the managerial strategy should remain in constant flux and be receptive to accommodate the political, economic, legal, competition, technology and market changes during the various event stages of the supply chain.

5 Contribution, limitation and future scope

This research imparts an unconventional approach to the study of fundamental variables for an AFSC by amalgamating stakeholder and CSF theory with that of system sustainability theory. It is pertinent to mention that the criticality associated with a CSF is dynamic and subject to change with reorientation and adjustment in other factors. Previous works have largely assumed a static view of CSFs. The study bridges this academic gap and identifies statistically relevant CSFs for system sustainability in the present scenario. The theoretical construct presented would assist in future comparative study in case of use of disruptive technology, change in government policy, etc. prompting review of presented CSFs. However, the developed model overlooks the inherent subjectivity and biases in the expert opinion that may influence the result. An attempt to validate and verify the proposed TISM-based hierarchical model using structural equation modelling (SEM) offers potential investigation area for the future researchers. In addition, the similar work can be expanded to include sustainability aspect in other supply chains, e.g., automobile, FMCGs, etc. by the supply chain researchers.

6 Conclusions

Sustainability positively impacts the society, environment and economy. System sustainability is crucial as it emphasises that the whole is greater than the sum total of its parts. The agriculture and food sector aspire to achieve production level sustainability and largely ignore the downstream processes in the product supply chain. This paper takes a system view of the sustainability for the AFSC that includes all stakeholder and identifies CSFs based on extensive literature survey and inputs from the industrial practitioners, subject experts and policy managers. A set of 11 CSFs is determined and the study presented a TISM digraph depicting the hierarchy of the CSFs focusing on the implementation aspect for the system-wide-sustainability. The MICMAC analysis presented highlights the driving and dependence power of the CSFs. The analysis shows that the government is the biggest actor and its regulation and policy is the most important critical variable that conditions the whole system.

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Appendix

Table A1 Interpretive matrix

	Critical success factors	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1	Integration of national agriculture market (CF1)	-	-	-	-	-	-	-	Integration NAM leads to robust ICT infrastructure for effective operation	-	-	-
2	Coordination and collaboration (CF2)	-	-	-	-	-	-	-	-	-	-	Positive coordination and collaboration mean minimum wastage and low cost leading to better customer satisfaction
3	Risk management (CF3)	-	-	-	-	-	-	-	-	Results in safe and quality food	-	-
4	Trust among the partners (CF4)	-	Improved confidence between partners lead to positive coordination and collaboration	Trust lead to better risk management and sustainability practices	-	-	Long-lasting successful relationship result in more business opportunities	-	-	-	-	-

Table A1 Interpretive matrix (continued)

	Critical success factors	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
5	Storage and processing facilities (CF5)	-	Enhance credibility and integrity	Advance technology of storage and processing ensure better risk management and incorporate sustainability practices	Lead to trust among partners by storing agri-food product in good condition	-	Advance facilities lead to coordination and transparency during distribution of agri-food product	-	-	-	Advance facilities share real time data about product and lead to established traceability system	-
6	Logistics network (CF6)	-	-	-	-	-	-	-	-	Facilitates safe and quality food	-	Provide quality food on time and take care of customer's expectation
7	Government regulations and policies (CF7)	Impose policies and regulations to control the system effectively	-	-	-	Provide funding and encouraging more investment to build storage capacity and processing units	-	-	Promote the use of advance technology and adoption	-	-	-

Table A1 Interpretive matrix (continued)

	Critical success factors	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
8	ICT infrastructure (CF8)	-	ICT-based coordination and collaboration	-	-	Ensures effective storage and processing management by using smart technology	-	-	-	-	Generate and process data for establishing the traceability system	-
9	Food quality (CF9)	-	-	-	-	-	-	-	-	-	-	Safe and quality food
10	Visibility and traceability (CF10)	-	-	-	-	-	Distribution of goods more transparent	-	-	-	-	-
11	Customer satisfaction (CF11)	-	-	-	-	-	-	-	-	-	-	-