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Modeling the key factors influencing the reduction of food loss and waste in fresh produce supply chains

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ABSTRACT

The purpose of this study is to develop a comprehensive framework by identifying and analyzing the key factors influencing the reduction of food loss and waste (FLW) in fresh produce supply chains (FPSCs) in developing countries, specifically India. This empirical study has identified eight influencing factors, representing the given context, from the literature (using content analysis) under the purview of management theories (namely, stakeholder theory, capabilities-based theory, and critical success factors theory) as well as data collected through semi-structured interviews from a group of selected experts. Further, Interpretive Structural Modeling (ISM) technique and Matriced' Impacts Croise's Multiplication Appliquée an un Classement (MICMAC) analysis are used as an integrated method to analyze the identified factors. Regulatory bodies and food policy along with market infrastructure are the most significant factors and have a high tendency to influence the reduction of FLW in FPSCs; therefore, require utmost consideration. The findings of this study are expected to enable managers and policy makers to uncover and understand the key factors. The insights from the findings will help in formulating policies and making strategic decisions regarding the reduction of FLW in FPSCs which will help in attaining sustainable development goals target on FLW.

1. Introduction

Food loss and waste (FLW) has emerged as a paramount concern on the global and regional sustainability agenda. Sustainable Development Goals (SDGs) are plans of action for people, planet, and prosperity (United Nations Summit, 2015). In particular, SDGs have a specific target (Target 12.3) to reduce FLW at each echelon of food supply chains (FSCs) by 2030. FLW has a negative impact on the hunger index, food quality and safety, food security, economic development, environmental conditions, and social prosperity (BCFN, 2012; FAO, 2013; Kumar et al., 2020). Moreover, increasing global population, food safety and global food security concerns demand to transform the unsustainable food supply chain (FSC) to a sustainable food supply chain (Mangla et al., 2018; Joshi and Visvanathan, 2019).

Food waste, a sub-set of food loss, is non-consumed food at the retail and consumer level while food loss is the change in the physical condition (decrease in edible food mass, not in inedible food mass-i.e., eggshells, banana peel, etc.) of the produce along the supply chain (Gustavsson et al., 2011; Thyberg and Tonjes, 2016). Reduction of FLW across the FSCs will have a direct impact on sustainability (through effective use of natural resources, decrease in the emission of greenhouse gases, and increase in food availability) which in turn will revolutionize food security concerns around the globe (Mena et al., 2011; Ghosh et al., 2015) and will help in meeting the global food demand of a projected 9 billion people by 2050 (Parfitt, 2010). Sustainability aspects of FSCs are significantly affected by the course of action through which food is produced, processed, transported, and consumed (Tsolakis et al., 2014). The reduction of FLW across the FSCs will help in fulfilling the societal needs, economic benefits, and ecological balance (Thyberg and Tonjes, 2016).

This study focuses on supply chains of agri-food of plant origin (fresh produce) having short shelf-life, even under the controlled climate conditions, commonly known as fresh produce supply chains (FPSCs). Fresh produce (fruit and vegetable), perishable in nature, has seasonal production with long throughput times and has a diverse produce range (Ahumada and Vilalobos, 2011; Gokarn and Kuthambalayan, 2019). The term 'fresh produce supply chain (FPSC)' refers to the supply chain of fresh produce that encompasses the activities (farming, wholesaling, warehousing, and retailing) from production to distribution stage and distribution to consumption. Moreover, this study considers FPSCs in

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general and does not focus on any one specific type of FPSC related to particular produce. Fresh produce is an integral part of our healthy diet and a vital source of nourishment, such as vitamins, minerals, and other nutrients (Zuurbier, 1999; Stanton, 2007). The production of fresh produce consumes resources such as water, land, energy, and other multiple input factors that are limited to produce sufficient food to meet future demand (BCFN, 2012). Waste of fresh produce across the supply chain is a non-productive use of rare resources (such as water, land, and energy) leading to environmental degradation and must be avoided (Gokarn and Kuthambalayan, 2017). FLW of fresh produce is known to increase with production. During the production and distribution process, fresh produce emits greenhouse gases into the air and this continues after the disposal of food waste in landfills (Thyberg and Tonjes, 2016; Porter et al., 2018). In addition, FLW has a direct negative impact on the income of both the producers and consumers (Thyberg and Tonjes, 2016). In addition to environmental and economic impacts, FLW also has social implications (Papargyropoulou et al., 2014; Thyberg and Tonjes, 2016). As is seen, the wastage across the FPSCs negatively impacts ecological conditions, food security, and sustainability (Gokarn and Kuthambalayan, 2017; Mangla et al., 2018). The reduction of FLW will have an immediate and significant impact on the livelihood of marginalized farmers and simultaneously it will increase the access of nutritious, safe, and affordable produce to the consumers affected by food poverty which in turn will ensure food security and increase labor productivity and wages (Haberl et al., 2011). Thus, a sound understanding of the impact of FLW provides a foundation for developing a comprehensive framework for the reduction of FLW in FPSCs which is of paramount importance. Reduction of FLW at each echelon of FPSCs has become a critical problem to be addressed for attaining SDGs target on FLW. Moreover, FLW at every stage of FPSCs is a common problem across the world, irrespective of the level of development and industrialization (Hodges et al., 2010). The maximum proportion of waste of fresh produce in an industrialized country is mostly at the consumer's end-often due to behavioral constraint while in developing countries losses of fresh produce is generally at farms and post-harvest stage--mostly due to inefficiency in FPSCs (Priefer et al., 2016).

The reduction of FLW in the context of FPSCs is a complex phenomenon and negatively affected by perishability, technological challenges, customer expectation, poor management, and infrastructure, along with supply chain uncertainties and risks (Gardas et al., 2018). Before measuring the impact of the phenomenon accurately, identification, and understanding of the interaction between the relevant factors is crucial (Golicic, 2005). In order to truly understand, accurately describe, and begin to explain the given complex phenomena, it is crucial to identify the key factors and structure the interrelationships among them. Several interdependent factors will play a significant role in the successful reduction of FLW across the FPSCs. This study develops a comprehensive framework to reduce FLW in FPSCs by identifying various factors, structuring interrelationships among them, and disentangling the key factors. Thus, this paper aims to address the following research questions.

RQ1. What are the key factors influencing the reduction of FLW in FPSCs?

RQ2. How are the key factors interrelated for the reduction of FLW in FPSCs?

RQ3. What are the most significant factors influencing the reduction of FLW in FPSCs?

This empirical and interdisciplinary research contributes to the conduit of the integration of marketing and operations management literature-specifically, supply chain management literature. More specifically, to the best of our knowledge, this is the first study that identifies and analyze industry-specific key factors influencing the reduction of FLW in FPSCs under the purview of stakeholder theory, capabilities-based theory, and critical success factors theory as well as input taken from the experts. Further, a comprehensive framework and two dimensional-diagram are developed to uncover the interdependencies and interrelationships between the key factors through empirical data. Additionally, this study focused on the entire FPSC rather than a particular supply chain echelon to identify, categorize, and analyze the factors necessary for the reduction of FLW in FPSCs in the Indian fresh produce industry. Hence, this study enriches the literature of fresh produce supply chain management focusing on the reduction of FLW under the purview of the abovementioned theories. Understanding the contextual relationships between the key factors will help the policy-makers and managers/owners effectively manage their resources and make strategic decisions for the reduction of FLW in FPSCs in turns which will help in attaining SDGs target on FLW.

Thus, this study is based on the following fundamental premises related to FPSCs that is covered in the coming sections. There is FLW across the FPSCs and FLW has specific causes. FLW can be reduced by eliminating or managing the causes. A theory-driven comprehensive framework will help in eliminating these specific causes and hence achieving the SDGs (target 12.3). Based on the aforesaid facts, the structure of the remaining paper is organized as follows. The literature review is covered in section 2. Then, the research method adopted for this study is described in section 3. Further, data analysis and findings are presented in section 4. Section 5 and Section 6 are dedicated to the discussion and contributions, respectively. Finally, the conclusion and directions for future research are covered in section 7.

2. Literature review

FLW across the FPSC in the context of developed countries is well documented (Priefer et al., 2016). However, little is known about FLW across the FPSC in the context of developing countries like India. This section reviews the relevant literature in the given context. First, it provides the theoretical perspectives (stakeholder theory, capabilities-based theory, and critical success factors theory) used in this study, then it provides a review of the literature on the causes of FLW in FPSCs and problem context. Finally, based on these backgrounds, research gaps are recognized.

2.1. Theoretical perspectives used in this study

This study attempts to address the reduction of FLW in FPSCs under the purview of three management theories, namely, stakeholder theory, capabilities-based theory, and critical success factors theory. Several studies have used these theories in different areas of management studies to underpin the given context. However, best to our knowledge, none of the studies have employed these theories for identifying key factors influencing the reduction of FLW in FPSCs and hence achieving the SDGs (Target 12.3). There is a lack of a holistic assessment of the approaches for reducing FLW. The FPSC is very complex and dynamic, influenced by external factors (stakeholders) and internal factors (firm's capabilities) that shape the availability and the delivery of the produce (Shukla and Jharkharia, 2012; Gokarn and Kuthambalayan, 2019). The reduction of FLW at a firm-level depends on how successfully it co-operates with its partners and in return how well these business partners cooperate with the firm (Matopoulos et al., 2007; Kaipia et al., 2013). This study contextualizes and operationalizes these three theories in identifying influencing factors such as external factors, internal factors, and performance-oriented factors as key dimensions to reduce FLW in FPSC. These theories provide a theoretical lens and logical basis in identifying the relevant factors from the literature potentially representing the context. Thus, drawn on the above arguments, identification of relevant factors from the literature under the purview of the aforementioned theories is necessary for the reduction of FLW in the given context.

2.1.1. Stakeholder theory

Stakeholder theory states that any group or individual who can affect or is affected by the achievements of the firms' objectives (Freeman,

2010). A firm involved in sustainable practices should satisfy the legitimate interest of various stakeholders (e.g., government, farmers, exporters, wholesalers, retailers, consumers, environment, and community). This theory is widely used in different areas of research to analyze firms' motivation for practicing sustainability (Yuen, 2017). However, there is limited or no studies in the area of FPSC involving stakeholder theory for identifying and analyzing the key factors influencing the reduction of FLW across the FPSCs. This study involves interactions with different stakeholders involved in an FPSC such as academicians and industry experts who helped to select the representative factors to reduce FLW across the FPSCs. Therefore, this theory is suitable for the given context problem as it involves different stakeholders having joint activities towards the reduction of FLW in FPSCs.

2.1.2. Capabilities-based theory

Capabilities-based theory states that capabilities are the firm's ability to use and leverage the firm's resources (Barney, 1991). Capabilities are responsible for the efficient and effective use of resources and they are achieved through organizational routines and practices (Dierickx and Cool, 1989). According to Winter (2003) capabilities can be categorized as operational capabilities (also known as 'lower-order' capabilities) and dynamic capabilities (also known as 'higher-order' capabilities). Farming, handling, sorting, packaging, storing, and transportation are important activities involved in any FPSC. Inefficiency in the execution of these activities is one of the main reasons for FLW in an FPSC (Bloemhof and Soysal, 2017). Operational capabilities of a firm aim to sustain the intrinsic characteristics of the produce through proper handling and packaging which further play an important role in improving the existing inefficiencies which cause FLW across the FPSCs (Mahalik and Nambiar, 2010). Relational capabilities, a type of dynamic capabilities help a supply chain firm in creating and maintaining good relationships with their supply chain partners by sharing information, risks, and profits proportionately (Evans and Laskin, 1994). In the case of FPSC, strategic relationships in terms of interdependence, common objectives, and balance of power help in minimizing the supply chain uncertainties and mitigating risks which in turn will help in reducing FLW at each stage of FPSCs.

2.1.3. Critical success factors theory

The research questions of this study are also well positioned within the ambit of critical success factors theory. Bullen and Rockart (1986) defined critical success factors theory as "the limited number of areas in which satisfactory results will ensure successful competitive performance for the individual, department, or organization. Critical success factors theory is the few key areas where 'things must go right' for the business to flourish and for the manager's goals to be attained." In order to achieve the desired goal, the most challenging and complex tasks are to facilitate decision-making at various levels. Critical success factors theory helps a firm to target the key factors which help in achieving the desired goals (Bai and Sarkis, 2013). Hence, it is required to consider the critical success factors theory for the identification of key factors influencing the reduction of FLW in FPSCs.

2.2. Causes of FLW in FPSCs

More generally but not specifically, there is FLW at each stage of an FPSC and the extent of FLW varies from one commodity to another commodity (Ahumada and Vilalobos, 2009, 2011, 2011; Yu and Nagurney, 2013). Some factors responsible for FLW are structural, related to infrastructure, and implementation of best practices at each echelon of the supply chain, while, others are systematic and also related to regulations and policies (Sawaya, 2017). FPSCs stakeholders need to identify and understand the interrelationships between the factors which can help in the reduction of FLW. However, it is a complex phenomenon as produce considered in this study is perishable in nature-has short shelf-life, easily get contaminated, seasonally produced, heterogeneous due to biological variations, dependence over a season, and continuous change in its quality. These complexities make the characteristics of the FPSC different from other supply chains, which act as inherent challenges in managing the FPSC for the reduction of FLW (Cook, 1999; Bai and Kendall, 2008; Ahumada and Villalobos, 2012). Furthermore, fluctuating demand, customer expectations for the availability of quality and safe produce throughout at fair price, and short lead time have made the FPSC more complex compare to supply chains of other products (Zuurbier, 1999; Van der Vorst and Beulens, 2002; Shukla and Jharkharia, 2013). These peculiar characteristics of produce and complexity present in FPSCs have a significant adverse impact on the reduction of FLW at each echelon such as production, harvesting, storage, distribution, and consumption (Kaipia et al., 2013).

At the production stage, FLW gets adversely affected due to seasonal factors, natural hazards, and diseases that are not fully controllable (Ahumada and Vilalobos, 2009; Gille, 2012; Porter et al., 2018). At the harvesting stage, FLW occurs largely due to poor harvesting planning such as product handling activities and quality inspection activities (Ahumada and Vilalobos, 2009; Raut and Gardas, 2018). Moreover, at the production and harvesting stage FLW occurs more because of the high crop yields and low demand for the produce in the market as well as lack of government support and regulations (Ahumada and Vilalobos, 2009; Kumar et al., 2020). FLW at the storage stage occurs primarily because of poor packaging efficiency and poor storage facilities (Murthy et al., 2009; Manikas and Terry, 2009; Raut and Gardas, 2018). At the distribution stage, FLW occurs mainly due to improper transportation planning and high transportation costs (Cai et al., 2010; Rijpkema et al., 2014). Food waste at the consumer stage generally occurs due to behavioral issues (Parfitt et al., 2010). Due to the perishability of fresh produce, it is difficult to practice inventories as a buffer against inconsistency in demand and transportation (Ahumada and Villalobos, 2009). Information sharing and coordination between the FPSC partners will help in reducing FPSC uncertainties, FPSC cost, and improving the traceability and delivery performance by reducing the lead time which in turn will help in preventing FLW in the FPSC (Manikas and Terry, 2009; Kaipia et al., 2013). Lack of communication among partners and deficit of adoption of advanced techniques are also important sources of FLW in FPSCs (Taylor and Fearne, 2009; Mena et al., 2011). Poor management of FPSC functions and insufficient amalgamation of innovations (process and technological) in the business are the major contributors of the FLW in developing countries like India (Shukla and Jharkharia, 2014; Balaji and Arshinder, 2016). However, trust, co-operation, and collaboration help in improving supplier-retailer relationships and hence reducing FLW across the FPSCs (Hingley et al., 2006). Demand uncertainty in FPSCs requires supply chain flexibility and responsiveness instead of economies of scale, which help in reducing FLW in FPSCs. To improve flexibility and responsiveness, FPSC stakeholders need to work in collaboration at each decision level (Aramyan et al., 2007; Kaipia et al., 2013). A performance measurement system allows a firm to monitor its practices and helps in improving its delivery or operational performance that leads to the reduction of FLW (Aramyan et al., 2007; Manikas and Terry, 2009; Gokarn and Kuthambalayan, 2019). Therefore, in order to reduce FLW across the FPSC, it is required to ensure that the produce delivered to the end consumer is in full quantity and in perfect condition, which will further help in achieving SDGs.

2.3. Problem context

In this study, the given phenomenon is complex which involves the exploration of known concepts into a new context such as developing countries like India. Region-specific analysis of the supply chain is important as the relative importance of factors impacting a waste reduction in FPSCs differs by region (Gokarn and Kuthambalayan, 2017).

According to India's National Horticulture Board report (NHB,

2015), India's diverse climate and soil ensure the availability of different types of fresh produce; is ranked as the second-largest producer of fresh produce in the world, after China. Fresh produce in India accounts for almost 90 percent of the total horticulture sector production in India (NHB, 2015). However, out of the total production of fresh produce in India, nearly 66 percent is consumed in fresh form, the wastage accounts for 30 to 32 percent, and only 2 to 4 percent is processed (Balaji and Arshinder, 2016). About 45 percent of fruit and vegetable produced for human consumption gets lost every year during post-harvest distribution in developing Asian countries like India (FAO, 2011, 2013; 2014). Furthermore, in the context of India, the FPSC entails mostly small farmers lacking the scale of economy and fresh produce retail shops dominated by small unorganized corner shops lacking market infrastructure. Still, a few modern food retail chains are growing at a significant pace in India (Reardon and Minten, 2011). According to the Global Hunger Index (GHI, 2016), India ranked 97 among 118 countries in the world, insisting on corrective measures to be taken immediately to lessen the current food crisis. Moreover, a larger and wealthier middle class in India will require/demand more fresh produce, and hence reduction of FLW is important for achieving regional and global food-security (Balaji and Arshinder, 2016). The reduction of FLW ensures higher income to the farmers as well as the availability of quality produce at low prices to the consumers (Balaji and Arshinder, 2016). Lack of technology, inefficient transportation, poor storage, and lack of information sharing accounts for the majority of FLW at the early stage of FPSCs in developing countries like India (Gustavsson et al., 2011; Gokarn and Kuthambalayan, 2019). FLW must be taken care of from the early stage of the supply chain where fresh produce passes through a chain consisting of different stakeholders such as farmers, local traders, intermediaries, wholesalers, retailers, and end consumers.

Most of the studies on FPSC are generic and lack a region-specific approach (Shukla and Jharkharia, 2013). In recent years, region-specific research addressing FLW issues from different aspects and approaches has increased. However, studies in the Indian context (a developing country) restrict attention to specific factors for the reduction of FLW or on a single issue at a specific supply chain stage. These are (i) traceability (Faisal and Talib, 2016), (ii) cold-chain (Joshi et al., 2009), (iii) information technology infrastructure (Parwez, 2014), (iv) food safety regulation (Shukla et al., 2014), (v) standards compliance (Sagheer et al., 2009), (vi) knowledge of waste at each stage (Murthy et al., 2009), and (vii) wastage at retail stage (Arivazhagan et al., 2012). Thus, these studies address a limited view of means to reduce FLW and lack theoretical perspective. Shukla and Jharkharia (2013) have reviewed the literature of agri-fresh produce supply chain and highlighted that researches in developing countries like India are generally state-funded and oriented towards increasing agri-food production rather than reduction of FLW. Recently, a few researchers have identified and analyzed the factors related to the reduction of FLW in the Indian context. For instance, Balaji and Arshinder (2016) have studied the interactions among causes of food waste and identified the prevailing causes across the Indian perishable food supply chain. They found that a lack of scientific methods in harvesting and a large number of intermediaries in the chain are the root causes of food waste. Nevertheless, Balaji and Arshinder (2016) have uncovered the causes of food wastage but are limited to the post-harvest sources of the existing problem, and most of the causes are limited to logistics activities. Gokarn and Kuthambalayan (2017) have identified and analyzed the challenges inhibiting the reduction of waste in the agri-food supply chain (AFSCs). They have identified four independent challenges (food characteristics, supply chain uncertainty, market infrastructure, and food policy and regulation) that play a key role in inhibiting the reduction of waste in AFSCs (not specific to FPSCs) and are limited to barriers only. The study conducted by Raut and Gardas (2018) on the fruit and vegetable supply chain to identify and model the causal factors (sustainable logistics barriers) of food waste in the Indian context is limited to post-harvest losses only. Similarly, the study conducted by Gardas et al. (2018) is also limited to post-harvest losses only.

Thus, the perishable nature of fresh produce, unorganized and inefficient supply chains of fresh produce, fluctuating supply and demand, growing global competition, and increasing consumer awareness towards food waste compel different stakeholders such as policy-makers and fresh produce firms (farmer, wholesaler, retailer, and exporter) of India to identify and prioritize the key factors that are significant for the reduction of FLW in FPSCs (Rong et al., 2011; Gokarn and Kuthambalayan, 2019).

2.4. Research gap

Based on the literature review, a few research gaps are recognized. This study is a rudimentary effort to fill these gaps. Few studies in the Indian context have identified and analyzed the factors, but they are focused on a particular domain (or supply chain echelon/activity) or post-harvest part of the FPSC, or they are limited to a specific functional area, rather than the entire supply chain. Moreover, none of the previous studies have identified factors under the purview of management theories influencing the reduction of FLW in FPSCs. Hence, a broader outlook grounded in theoretical perspectives is required in identifying the key factors influencing the reduction of FLW in FPSCs for a particular region (i.e., a developing country like India) and establishing contextual inter-relationships among them. Different types of factors influence the reduction of FLW in different kinds of food industries. Given this, factors influencing the reduction of FLW in a particular industry may not impact in a similar way to any other industry. Additionally, the reduction of FLW is influenced by many factors that have interactive relationships. Thus, a set of representative factors is required to be identified and analyzed to reduce FLW in the Indian fresh produce industry. Since managerial decision-making is based on preference, so prioritizing and categorizing the key factors for the reduction of FLW in FPSCs is required to be addressed. Hence, a theory-driven holistic decision framework is required to be modeled in the given context.

3. Research method

Drawn on interpretive research philosophy, this research is a theory-building exploratory study that develops a comprehensive framework for the reduction of FLW across the FPSCs in the given context. Undoubtedly, an FPSC is a complex and interconnected chain of various entities, mainly focusing on making various decisions to meet the requirements of the end consumers. A comprehensive and deep understanding of the given complex phenomenon can be achieved by collecting empirical data from the experts (Creswell, 2014). To attain this, a thorough knowledge of the important factors in the given context must be explored. Therefore, a mix-method approach is employed in this study to identify representative factors and structure the relationships between the factors of the given context. Fig. 1 illustrates the framework of research method deployed in this study that reflects the steps involved in achieving the aforesaid research questions.

3.1. Data collection

A semi-structured interview is widely used for collecting data from the field when the issues are complex or open-ended (DiCicco-Bloom and Crabtree, 2006). Moreover, to investigate a complex issue, it is often both necessary and desirable to assemble a group of people of diverse backgrounds (Whetten, 1989). Therefore, in this study, a semi-structured interview is used to obtain the opinions from a group made up of specialists (academia) having content knowledge relevant to the different aspects of the situation, and stakeholders (industry) who may be affected in some way by the outcome of the investigation. Nevertheless, there are not many experts having sufficient knowledge and experience available in the Indian agri-food industry, more specifically the fresh produce industry. In the context of India, it becomes

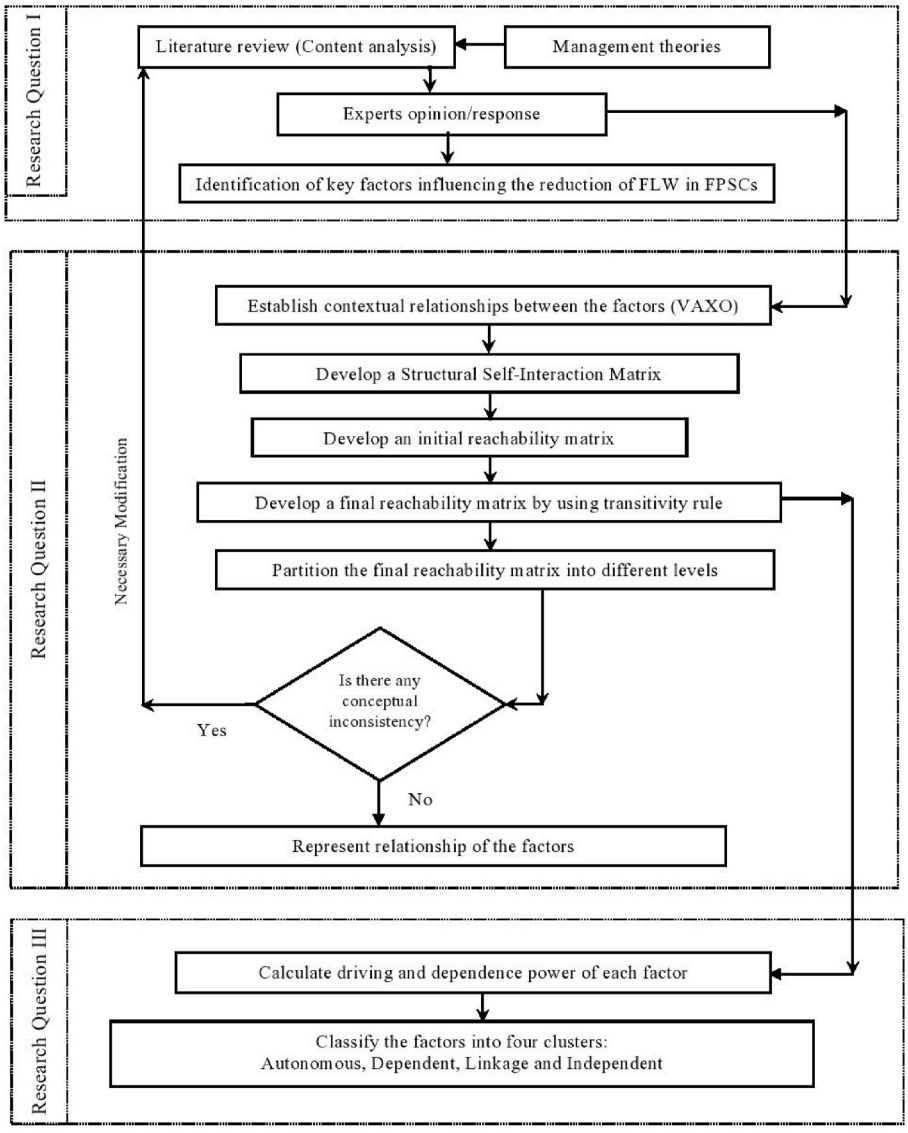

Fig. 1. Flow diagram for an integrated research method.

challenging and time-consuming to search the possible experts in such a sector, which is unorganized. Hence, the purposive sampling technique (Saunders et al., 2015) was used to select the suitable experts, ensuring that selected experts met the inclusion criteria: experts should be conversant with FLW in FPSCs and having experience of at least five years in their respective domains. According to Saunders et al. (2015), in the exploratory study there is no specific criteria for sample size. A panel consisting of eleven experts and professionals (six from academia and five from industry) having knowledge about FPSCs and FLW was consulted during "the Sixth Biennial Supply Chain Management Conference" at IIM, Bangalore, in December 2018 (please see Table 1). Experts from industry were having responsibilities over supply chain operations in fresh produce industry, and experts from academia were having in-depth knowledge of the fresh produce sector in India. Experts were consulted for selecting the representative factors and establishing the contextual relationship between these factors. Comprehensiveness and

Table 1
Profile of experts.

Expert Number	Years of Experience	Area of expertise	Area of expertise	Role in supply chain	Designation
1	16	Industry	–	Procurement and marketing	Chief Executive
2	08	Industry	–	Procurement	Store Manager
3	15	Industry	–	Producer and distributor	Managing director
4	11	Industry	–	Wholesaler	Senior Manager
5	15	Industry	–	Retailer	Senior Manager
6	20	Academics	Supply chain	–	Professor
7	12	Academics	Food supply chain	–	Associate Professor
8	10	Academics	Horticulture	–	Associate Professor
9	07	Academics	Food supply chain	–	Assistant professor
10	05	Academics	Agribusiness	–	Assistant professor
11	05	Academics	Agri-food supply chain	–	Assistant professor

parsimony were two broad tenants for judging the extent to which identified factors are representing the given phenomena of interest (Whetten, 1989). To facilitate the experts for the effective judgment, problem area, and a short description of each factor was provided (please see Appendix A). Additionally, a few questions were framed to make their response more structured during the discussion. These questions were as follows: is the description of each factor is meaningful or not; is there any factor that is not relevant in the given context; is there any factor that overlaps with any other factor; and is there any other important factor that is not in the list. The responses of each expert were taken against the above-mentioned questions. This was to ensure content validity of the identified factors in the given context. Organizational reports, government reports, enterprise relevant documents, and various other documents were considered as replenishment of data sources to achieve triangulation. Moreover, before empirical data collection, a literature review related to the FPSC and FLW was conducted by using content analysis to get a clear understanding of the subject domain being explored and simultaneously identify the representative factors.

3.2. Data analysis method

After collecting the data from the field, the next step is to analyze it from the informants' point of view. As the problem considered in this study is of the multi-criteria decision type, so, an integrated research method was used to analyze the empirical data collected through semi-structured interviews. Interpretive Structural Modelling (ISM) and Matriced' Impacts Croise's Multiplication Appliquée an un Classement (MICMAC) approach as an integrated research method was used in this study. A multi-criteria decision making (MCDM) technique (such as ISM and MICMAC) helps in evaluating various factors to improve the efficiency of an FPSC that can optimize the decision-making at each echelon (Banasik et al., 2017). Additionally, content analysis was used to identify the relevant factors from the literature. The factors influencing the reduction of FLW in FPSCs were identified by reviewing the literature under the backdrop of stakeholder theory and capabilities-based theory, and critical success factors theory. Next, identified factors were selected and analyzed based on inputs taken (through a semi-structured interview) from a group of selected experts of the Indian agri-food industry and academia (Please see Table 1). Further, the application of content analysis, ISM, and MICMAC analysis in the context of this study is discussed.

3.2.1. Content analysis

To identify representative factors affecting the reduction of FLW in FPSCs, qualitative content analysis was used. Relevant articles were collected from the Scopus database to maintain a high level of rigorousness. Moreover, only peer-reviewed journals were considered for the selection of articles. Conference proceedings, technical reports, and works in progress were excluded. Since the FPSC is comparatively a new area of study, so the search was limited to research articles published between the period 2000 to 2018. The keyword 'fresh produce supply chain' was used to collect the research articles from the Scopus database. In the initial search process, a total of 70 research articles were found limited to the area of business, management, and accounting. Further, based on the approach advocated by Pittaway et al. (2004), the criteria for the inclusion/exclusion of research papers were defined for shortlisting those papers only which were relevant in the given context. Either abstracts or articles focus on the fresh produce supply chain with particular attention to those addressing FLW were included. Rest research papers were excluded. To achieve this criterion, initially, titles and abstracts of all the 70 research articles were read, and suitable articles were included; then, full papers were read from the remaining lots of the papers, and suitable articles were considered. Through this process, all papers were grouped into three categories: Category A contains papers with a focus on both FPSC and FLW. Category B includes papers with a predominant focus on the FPSC but less or insignificant reference to FLW. Category C contains papers with a major focus on the FPSC, but not addressing FLW. The papers included in Category C (44 articles) were excluded as they were not fulfilling the given criteria. Category A and Category B have a total of 26 articles, were considered in full, and analyzed in-depth for the identification of representative factors.

While identifying the representative factors from the shortlisted articles, the concept of first- and second-order constructs was used, where the second-order construct has a higher level of abstraction. First-order factors identified through this process were haphazard and disorganized. Under the purview of stakeholder theory, capabilities-based theory, and critical success factors theory, factors were identified (first-order) and further categorized into higher-order to recognize the significant concepts and underlying patterns as suggested by (White and Marsh, 2006; Seuring and Gold, 2012). First-order factors represent those factors that were generated from the literature representing the given context. Further, first-order factors that seemed to have common meaning were grouped under the second-order factors named as representative factors. Finally, second-order factors were categorized into aggregate dimensions which represent the key concepts in the reduction of FLW in the Indian FPSCs. However, a few first-order factors (like knowledge about quality seeds, procurement channels, and top-level commitment, etc.) were not considered as they were not found in more than two articles and they were not associated with any second-order factors. This process was exercised to retain comprehensiveness and parsimony as two broad tenants in identifying the factors responsible for influencing the reduction of FLW in FPSCs.

3.2.2. ISM analysis

Having identified the representative factors, the next step in understanding the complex phenomenon is to establish the relationships between them. The selected key factors are used as inputs to process the ISM method to establish the structural relationships and develop a hierarchical model. Steps for developing an ISM model are adopted from Mathiyazhagan et al. (2013) and Sarabi et al. (2020).

3.2.3. Development of structural self-interaction matrix (SSIM)

To find the contextual relationship between the key factors, pair-wise (8*8-8 = 56) comparison questions were developed. Same experts (please see Table 1) were asked to respond to each relationship in terms of yes or no. Further, these relationships between the factors are analyzed and converted into SSIM by using VAXO. Four symbols (VAXO) are used to denote the path of association between the factors (i and j). Where i represents the factors in rows, and j represents the factors in columns.

V: Factor *i* will assist in alleviating factor *j*.
A: Factor *I* will be alleviated by factor *j*.
X: Factor *i* and *j* will assist in alleviating each other.
O: Factor *i* and *j* are unrelated.

3.2.4. Development of reachability matrix (RM)

Reachability matrix is developed in two steps: the initial reachability matrix and then the final reachability matrix. In the first step, the SSIM is reformed into a binary matrix, known as the initial reachability matrix, converting V, A, X, and O by '1' and '0' as per the case.

The convention for the substitution of '1' and '0' are as follows:

- If the entry in the cell (i, j) in the SSIM is V, then the cell (i, j) entry is converted into 1 and the cell (j, i) entry is converted into 0.
- If the entry in the cell (i, j) in the SSIM is A, then the cell (i, j) entry is converted into 0 and the cell (j, i) entry is converted into 1.
- If the entry in the cell (i, j) in the SSIM is X, then the entry in both the cells (i, j) and (j, i) is converted into 1.
- If the entry in the cell (i, j) in the SSIM is O, then the entry in both the cells (i, j) and (j, i) is converted into 0.

Reachability matrix is obtained by incorporating the transitivity rule which says that if a variable A is related to variable B and variable B is related to the variable C, then variable A is also related to variable C.

3.2.5. Level partitions

From the final reachability matrix the antecedent and reachability set for each factor are achieved. The reachability set for a specific factor includes the factor itself and the other factors, which may be achieved by it. The antecedent set consists of the factors itself and the other factors, which may assist in achieving it. The intersection of these two sets is obtained for all factors. The factor, for which the reachability and the intersection sets are equivalent, is assigned at the level I factor for the first round. After assigning the top-level factor (level 1), it is dropped from the list of enduring factors. This process keeps on repeating until each factor gets its level.

3.2.6. Formation of ISM-based model

The ISM based model is developed from the final reachability matrix and level partition.

3.2.7. MICMAC analysis

Finally, MICMAC analysis is used to categorize each factor into different groups based on their driving power and the dependence power (Mathiyazhagan et al., 2013). MICMAC analysis has the advantage over other tools as it can analyze the scope of each factor considering the strength of relationships between the factors (Bhosale and Kant, 2016). The driving-power and dependence-power of each factor are computed by totaling the numerical values along the row for driving power and along the column for dependence power.

4. Results

This section presents the outcomes of each method used to obtain the aforesaid objectives of this study. The outcomes of each application is discussed as follows.

4.1. Outcomes of content analysis

Through this process, a list of ten factors important for the given problem area was identified from the shortlisted research articles and is presented in Table 2.

However, identifying the factors only through the process of content analysis from the existing literature has certain limitations (Yu et al., 2014). There may be some overlapping between the identified factors. For overcoming this limitation, semi-structured interviews with the group of selected experts (please see Table 1) who have knowledge of FPSCs and FLW in the Indian context were consulted to assist in selecting the key factors from the list of representative factors. Based on their responses, changes were made. Two factors, namely, government support (due to overlapping with regulatory bodies and food policy) and consumer behavior (not remarkably important in the Indian context) were dropped from the list of the representative factors. Consumer behavior plays an insignificant role in causing food waste in India (Gokarn and Kuthambalayan, 2017). In India, because of less purchasing power, availability of the market for any grade of produce, and their eating habits, very little food is wasted at the consumer end. For the government support factor, only one expert was in favor while for the consumer behavior factor, only three experts were in favor, warranting not to consider these two factors for further analysis.

As a result, a total of eight factors was selected as key factors influencing FLW reduction in FPSC. The eight factors were selected based on the principle of "The minority gives away to the majority" (Shen et al., 2016). This means a factor was selected if six or more experts (out of 11 experts) agreed that it was an influencing factor for the reduction of FLW in Indian FPSCs. These eight factors are explained briefly in the given system of the problem in the following subsections.

Table 2
Evidence for identifying representative factors.

First-order	Second-order	Literature	Aggregate dimensions
Food policy Regulatory framework Food safety & quality measure Training and educating	Regulatory bodies and Food policy	Shukla and Jharkharia (2013); Kirezieva et al. (2013); Yu and Nagurney (2013); Shukla et al. (2014); Gokarn and Kuthambalayan (2017)	External factors
Financial incentives Minimum support price	Government support	Joshi et al. (2009); Shukla and Jharkharia (2013); Balaji and Arshinder (2016); Gardas et al. (2018)	External factors
Market system Cold chain facility	Market infrastructure	Murthy et al. (2009); Joshi et al. (2009); Balaji and Arshinder (2016); Gardas et al. (2018); Gokarn and Kuthambalayan (2017)	External factors
Awareness Consumer attitude Consumer habits	Consumer behavior	Joshi et al. (2009); Parfitt et al. (2010); Gokarn and Kuthambalayan (2017)	External factors
Harvesting planning Transportation planning Packaging efficiency Storage facility	Logistics management	Cai et al. (2010); Ahumada and Vilalobos (2011); Balaji and Arshinder (2016); Raut and Gardas (2018)	Internal factors
Coordination Trust Demand forecasting Supply chain contracts Partnerships	Relationships management	Hingley et al. (2006); Matopoulos et al. (2007); Clements et al. (2008); Taylor and Fearne (2009); Kaipia et al. (2013)	Internal factors
Technical expertise Tracking and tracing technology Information sharing Technical support	Information and communication technology	Kaipia et al. (2013); Tanksale and Jha (2015); Gokarn and Kuthambalayan (2017); Gardas et al. (2018)	Internal factors
Change in the order quantity Change in delivery location	Flexibility	Aramyan et al. (2007); Trienekens et al. (2008); Kaipia et al. (2013); Qrunfleh and Tarafdar (2014)	Performance-oriented factors
Delivery quickly Resolve complaint quickly	Responsiveness	Aramyan et al. (2007); Trienekens et al. (2008); Blackburn et al. (2009); Rong et al. (2011)	Performance-oriented factors
Economic indicators Environmental indicators Social indicators	Performance measurement metrics	Aramyan et al. (2007); Trienekens et al. (2008); Qrunfleh and Tarafdar (2014)	Performance-oriented factors

4.1.1. Regulatory bodies and food policy (F1)

Regulatory bodies and food policy addresses regulating food industry activities that include marketing unhealthy foods and promoting purchases in large portions, which contribute to poor diet and waste. In the Indian scenario, it is the extent to which the actions of a firm get

influenced by existing food policy and market regulation in the fresh produce industry. Considering the importance of fresh produce, the regulatory bodies should play a leading role in formulating the food policies related to the quality and safety of fresh produce (Kirezieva et al., 2013). Food policies made by the government should be reliable along the FPSC and mutually reinforcing and non-contradictory (Shukla and Jharkharia, 2013). Quality and safety certification, less use of chemicals and pesticides will help in controlling the quality and safety of fresh produce (Yu and Nagurney, 2013). The capacity and impact of regulatory bodies and food policies in India are relatively incompetent, as there are inefficient laws and regulations related to food (Shukla et al., 2014). Thus, regulatory bodies and food policy is considered as a representative factor that frame supportive food policy to promote sustainable practices in FSCs, which in turn will help in reducing FLW.

4.1.2. Responsiveness (F2)

Responsiveness refers to the ability of the fresh produce supply chain to respond firmly and within a suitable timeframe to customer requests or orders. Customer expectation and demand urge fresh produce firms to be more responsive to customer needs. Supply chain responsiveness is the ability of the supply chain to hastily address requests in the marketplace (Kritchanchai and MacCarthy, 1999). Since fresh produce is perishable, so an FPSC is expected to respond efficiently and effectively to customer orders to improve firm performance. Making produce available quickly, minimizing delivery cycle time, delivering the right product at the right place, and responding quickly to the customers complain will make an FPSC more responsive resulting in superior performance in terms of reducing FLW (Aramyan et al., 2007). A responsive FPSC minimizes market time, which will help in reducing FLW. Hence, responsiveness is considered as a representative factor for the reduction of FLW in FPSCs in India.

4.1.3. Performance measurement metrics (F3)

Performance measurement metrics (PMM) is a set of parameters that enable a firm to measure the respective performance indicators related to the respective functions in a given time frame (Yu and Nagurney, 2013). It is an important factor that enables a firm to evaluate and control its functions (Vorst et al., 1998). To measure the performance holistically, adequate performance measurement metrics are required to be developed for a fresh produce firm (Aramyan et al., 2007; Trienekens et al., 2008). Sustainability metrics in FSC can be used to measure three dimensions, namely, economic (increase in profit, increase in return on investment, decrease in cost), environmental (reduction in food waste, reduction in energy waste, reduction in emission of greenhouse gas, and carbon footprints), and social (product quality and safety, fair wages, and ethical pricing). Economic and social dimension metrics are also influenced by FLW (Gokarn and Kuthambalayan, 2017). These three metrics help in measuring the FPSC performance (in terms of quality and wastage of the produce) and are important for adopting sustainable practices in the fresh produce industry to reduce FLW.

4.1.4. Market infrastructure (F4)

Market infrastructure refers to essential facilities required for cost-effective marketing, to minimize post-harvest FLW, and to reduce health risks. The condition of market infrastructure for the fresh produce sector in the context of India is relatively under-developed. India's fresh produce industry lacks in the cold chain; as a result, fresh produce is generally transported through non-refrigerated trucks, which causes food waste (Balaji and Arshinder, 2016). Due to poor processing infrastructure and inadequate storage facilities, fresh produce - having a short shelf-life, is either tends to go wasted or sold at lower prices. Private capital investment is lacking for temperature-controlled transportation, trading facilities, and food processing units due to the substantial fixed cost (Vanek and Sun, 2008; Gokarn and Kuthambalayan, 2019). In a developing nation, like India, inefficiency in FPSCs is due to lack of government support, lack of temperature-controlled transportation mechanism, poor packaging, lack of skilled workforce, inadequate storage facility, and poor processing infrastructure (Gokarn and Kuthambalayan, 2017). However, the Indian government has allowed 100 percent foreign direct investment (FDI) and certain subsidies in the food processing industry. Thus, trading facilities, physical infrastructure (e.g., transportation infrastructure) technological infrastructure (e.g., Internet), and foreign direct investment play a vital role in building a market infrastructure of any country that will support sustainable practices to reduce FLW in FPSCs.

4.1.5. Flexibility (F5)

Flexibility refers to the capability in which the supply chain of a fresh produce firm responds to cope with changes in demand and the business environment to reduce the uncertainty causing food waste. As diversity and uncertainty present in FPSCs increase, firms need to respond by adding flexibility as a key strategy (Shukla and Jharkharia, 2013). The flexibility attribute of an FPSC describes the ability to respond to external influences and the ability to change to improve its performance in terms of the reduction of FLW. It may also be defined as the ability to cope with change or respond to provide service or products to customers with little penalty in terms of time, cost effort, or performance (Upton, 1994). The flexibility of a fresh produce firm helps in formulating the strategy to reduce the uncertainty in FPSCs. Order flexibility, delivery flexibility, and level of adaptability are the indicators to measure flexibility (Aramyan et al., 2007). Flexibility can improve a firm's competitiveness, particularly for the decision-making process, which in turn will help in reducing produce wastage across the FPSCs.

4.1.6. Information and communication technology (F6)

Information and communication technology (ICT) refers to all the technology used to share the flow of information across the fresh produce supply chain to meet the customers' orders. It can be an important tool to improve the efficiency and effectiveness of an FPSC (Salin, 1998; Iakovou et al., 2015). ICT is useful in various supply chain activities, such as procurement, production scheduling, inventory management, transportation, order processing, and customer services (Lancioni et al., 2000). Traditional Indian FPSCs are fragmented and run by a large number of unorganized intermediaries (Rajkumar, 2010). Lack of information sharing, across the FPSC, results in over or under the demand for fresh produce that gives rise to the problems such as wastage of produces, price fluctuation, and low profitability (Rais and Sheoran, 2015). Dandage et al. (2017) have suggested that ICT is helpful in tracing the fresh produce throughout the transit to control FLW in Indian FPSCs. Adoption and innovation in ICT in Indian FPSCs will significantly help in reducing transaction costs and improving market time hence reducing wastage. So, ICT can play a major role in achieving competitive advantages by reducing FLW across the FPSCs.

4.1.7. Logistics management (F7)

Logistics management helps in meeting customer demands through the planning, control, and implementation of the operative movement and storage of fresh produce from the point of origin to the point of consumption. It is the extent to which a fresh produce firm manages the internal operational activities of its FPSC to implement sustainability concepts to reduce FLW. Logistics management of a fresh produce firm includes procurement, transportation, inventory, and fleet management (Xiao et al., 2008; Dani, 2015). The procurement and distribution of fresh produce is a costly process in the Indian fresh produce industry because of the presence of geographically dispersed producers (Gokarn and Kuthambalayan, 2017). Considering these costs in FPSCs, optimizing the distance travel and using the 'greener' logistical options could result in a reduction in FLW as well as in carbon emissions. Moreover, in the case of FPSCs, logistics management is complicated due to the seasonal fluctuation in demand and supply (Broekmeulen, 1998). A firm competent in its logistics management enables it to implement sustainable practices in FPSCs, which in turn will reduce FLW at each

level.

4.1.8. Relationship management (F8)

Relationship management is the extent to which a fresh produce firm manages the relational activity of its supply chain partners to improve its performance in terms of reduction in FLW.

Complexities and uncertainty in FPSCs lessen the coordination at each level, which results in a significant increase in FLW. Relationships across the FPSCs can be improved by collaborating with a partner in making decisions, managing the conflicts, aligning their goals, and creating win-win situations for themselves (Hingley et al., 2006; Blackburn and Scudder, 2009). This can be achieved through backward integration, forward integration, or vertical integration strategy (Batt, 2003). There should be transparency and mutual sharing of the information related to the supply and demand for fresh produce between the partners at each level of the supply chain (Shukla and Jharkharia, 2013). However, the fresh produce industry in India is unorganized, and each supply chain partners work in isolation. They are working with each other without any formal contract, which results in a lack of trust and transparency among them. Hence, relationship management plays a crucial role in reducing FLW in FPSCs.

4.2. Outcomes of ISM analysis

4.2.1. SSIM

Based on the outcome of the contextual relationships, the SSIM is developed for the selected key factors, which is presented in Table 3.

4.2.2. Reachability matrix

The initial reachability matrix and the final reachability matrix of the factors are developed, as shown in Tables 4(a) and 4(b) respectively.

4.2.3. Level partitions

In this study, all the eight factors achieved their level after five times of iteration as shown in Table 5. These five levels will help in developing the ISM base model.

4.2.4. ISM based model

In the ISM based model (please see Fig. 2), the first level factor of level partitioned (level I, here), is positioned at the top and second level factors occupy the position just below the top-level factor. Likewise, the other factors are placed in the hierarchy according to their levels until the bottom level factor (level V, here) is placed at the lowest position. In this study, ISM model has five levels of hierarchy from level I to level V.

Factors regulatory bodies and food policy (F1) along with market infrastructure (F4), at level V (level partition-Table 5) are placed at the bottom of the ISM based model (see Fig. 2). This reflects that both factors, regulatory bodies and food policy (F1) and market infrastructure (F4), are the most important factors, meaning, these factors will affect the impact of all the remaining six factors. These factors require the utmost consideration while making decisions in the early satge to understand their impact on other factors in reducing FLW in FPSCs. Developing the infrastructure and formulating effective food policy will enable a fresh produce firm to build capabilities in terms of information and communication technology (F6), logistics management (F7), and relationship management (F8) directly (all three factors are placed at level IV). These three factors, in terms of capabilities, will help in leveraging flexibility (F5) of an FPSC, which in turn will improve the responsiveness (F2), resulting in the reduction of FLW. Performance management metrics (F3) is at Level I in the level partition (please see Table 5) and placed at the top of the model. This reflects that it is influenced by all remaining factors and helps in measuring the performance of a fresh produce firm in terms of the reduction of FLW in the Indian context.

Table 3
Structural self-intersection matrix (SSIM).

S/N	List of factors	F8	F7	F6	F5	F4	F3	F2	F1
F1	Regulatory body and food policy	V	V	V	V	O	V	V	–
F2	Responsiveness	A	A	A	A	O	V	–	
F3	Performance measurement metrics	O	A	A	A	O	–		
F4	Market infrastructure	O	V	O	O	–			
F5	Flexibility	A	O	A	–				
F6	Information and communication technology	A	V	–					
F7	Logistics management	V	–						
F8	Relationship management	–							

4.3. Outcomes of MICMAC analysis

Considering the summated values of each factor, a graphical diagram is plotted for each factor by treating dependence and driving power (please see Table 4(b) of each factor as X and Y coordinates, respectively, as shown in Fig. 3.

The results of MICMAC analysis are represented through a graph divided equally into four clusters, namely: autonomous, dependent, linkage, and independent.

Autonomous factors group: The factors that are located in the first quadrant (I) have the lowest driving and dependence power and are known as autonomous factors. The autonomous factors are relatively detached from the system, and so they have less impact on the system. In this study, no factor is found under the autonomous category (Quadrant I). The absence of such factors in this study indicates that all the representative factors play an important role in reducing FLW in FPSCs.

Dependent factors group: The factors that are located in the second quadrant (II) have low driving power, but the highest dependence power. The factors positioned in this quadrant are known as dependent factors. Factors present in this quadrant are flexibility (F5), responsiveness (F2), and performance measurement metrics (F3). Performance measurement metrics (F3) has a dependence power of eight and driving power of one, indicating fresh produce firms in India are less self-interested in using respective metrics to measure the performance of their FPSC in terms of FLW.

Linkage factor group: Factors having high driving and dependence power are known as linkage factors, located in quadrant III. They are unstable, and any action on them will reflect the impact on others. This group contains information and communication technology (F6), logistics management (F7), and relationship management (F8), which are classified as linkage factors. They have a strong driving power (six) as well as strong dependence power (5), and all three are placed in the same position in this quadrant.

Independent factors group: The factors that are located in the fourth quadrant (IV) have the highest driving power, but low dependence power. The factors positioned in this quadrant are known as independent factors. Factors, regulatory bodies and food policy (F1), and market infrastructure (F4) are located in the fourth quadrant (IV) and categorized as independent factors. They are having the highest driving power (seven) and lowest dependence power (one).

5. Discussion

The driving factors, namely, regulatory bodies and food policy (F1) along with market infrastructure (F4) (see Fig. 3) are important factors and are regarded as 'key factors'. Regulatory bodies support is required for horizontal integration of small farmers through cooperatives (Mangla et al., 2018) and various initiatives are essential for educating and training supply chain actors to prevent FLW (Sharma et al., 2019). Poor infrastructure is often regarded as a major reason for FLW in the early

Table 4
Reachability matrix.

(a) Initial reachability matrix

Factors	F1	F2	F3	F4	F5	F6	F7	F8
F1	1	1	1	0	1	1	1	1
F2	0	1	0	1	1	0	0	0
F3	0	0	1	0	0	0	1	0
F4	0	0	1	1	0	1	0	1
F5	0	0	0	0	1	0	0	1
F6	0	1	0	1	0	1	1	1
F7	0	0	1	0	1	0	1	1
F8	0	0	0	0	0	0	0	1

(b) Final reachability matrix

Factors	F1	F2	F3	F4	F5	F6	F7	F8	Driving Power
F1	1	1	1	0	1	1	1	1	**7**
F2	0	1	1	0	0	0	0	0	**2**
F3	0	0	1	0	0	0	0	0	**1**
F4	0	1	1	1	1	1	1	1	**7**
F5	0	1	1	0	1	0	0	0	**3**
F6	0	1	1	0	1	1	1	1	**6**
F7	0	1	1	0	1	1	1	1	**6**
F8	0	1	1	0	1	1	1	1	**6**
Dependence Power	**1**	**7**	**8**	**1**	**6**	**5**	**5**	**5**	**38/38**

Table 5
Label partition for factors: iteration I - iteration V.

Factors	Reachability set	Antecedent set	Intersection set	Level
Iteration I				
F1	F1,F2,F3,F5,FF6,F7,F8	F1	F1	
F2	F2,F3	F1,F2,F4,F5,F6,F7,F8	F2	
F3	F3	F1,F2,F3,F4,F5,F6,F7,F8	F3	I
F4	F2,F3,F4,F5,F6,F7,F8	F4	F4	
F5	F2,F3,F5	F1,F4,F5,F6,F7,F8	F5	
F6	F2,F3,F5,F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	
F7	F2,F3,F5,F6,F7,F8	1,4,6,7,8	F6,F7,F8	
F8	F2,F3,F5,F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	
Iteration II				
F1	F1,F2,F5,F6,F7,F8	F1	F1	
F2	F2	F1,F2,F4,F5,F6,F7,F8	F2	II
F4	F2,F4,F5,F6,F7,F8	F4	F4	
F5	F2,F5	F1,F4,F5,F6,F7,F8	F5	
F6	F2,F5,F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	
F7	F2,F5,F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	
F8	F2,F5,F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	
Iteration III				
F1	F1,F5,F6,F7,F8	F1	F1	
F4	F4,F5,F6,F7,F8	F4	F4	
F5	F5	F1,F4,F5,F6,F7,F8	F5	III
F6	F5,F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	
F7	F5,F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	
F8	F5,F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	
Iteration IV				
F1	F1,F6,F7,F8	F1	F1	
F4	F1,F4,F6,F7,F8	F4	F1,F4	
F6	F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	IV
F7	F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	IV
F8	F6,F7,F8	F1,F4,F6,F7,F8	F6,F7,F8	IV
Iteration V				
F1	F1	F1	F1	V
F4	F4	F4	F4	V

stages of FPSCs in India (Balaji and Arshinder, 2016; Gokarn and Thyagaraj, 2017). A comparison of the results of this study with previous studies such as Kumar et al. (2020) on structuring the elements of food waste across the FSC supports the result of this study to some extent by placing regulatory bodies and food policy along with market infrastructure at the bottom of ISM hierarchy. Moreover, a study carried by Gokarn and Thyagaraj (2017) have also considered these two factors in the context of AFSCs and found them as independent factors based on MICMAC analysis, while, Balaji and Arshinder (2016) has found poor logistics infrastructure as an important factor based on ISM analysis. The reason for the difference with the findings of Balaji and Arshinder (2016) maybe because they have selected the factors from the perspective of post-harvest losses and most of them are focused on logistic activities.

This study finds ICT, logistics management, and relationship management as linkage factors which is somewhat in line with the findings in the previous studies. Gokarn and Thyagaraj (2017) have identified ICT as linkage factors; Balaji and Arshinder (2016) have information technology and inventory management-related factors as linkage factors; Kumar et al. (2020) found traceability, horizontal integration, and ICT as linkage factors. All these studies have found information technology as a linkage factor. This may be because new technology such as the internet of things, blockchain, and artificial intelligence have vast scope in developing countries for the reduction of FLW in FPSCs (Kumar et al., 2020). Improvements in any of these linkage factors positively influence coordination at supply chain interfaces, cross-functional decisions, measurement and diagnosis of food waste, and relationships with suppliers and customers. As a result, fresh produce firms will be more capable of making strategic decisions to reduce FLW across their supply chain which in turn will improve the environmental (e.g., natural resource utilization), social (e.g., food security, and economic (e.g., profit margin) conditions in long-term.

Out of eight key factors, performance-oriented factors such as flexibility, responsiveness, and performance measurement metrics are new factors considered in the given context. Previous studies have not considered performance-oriented factors as a vital factor/element in the context of FLW and FPSCs. However, performance-oriented factors are crucial in the context of the reduction of FLW across FPSCs. Aramyan et al. (2007), in their study, argued that performance measurement metrics, which include the characteristics of agri-food, are capable of measuring the performance of FPSC successfully. Gokarn and Thyagaraj (2019) have used flexibility and responsiveness as means of delivery performance which helps in reducing FLW across FPSCs in a sustainable way.

In this study, all eight key factors are categorized as independent factors, linkage factors and dependent factors. The relationships between these three groups justify the resource-based view and stakeholder theory. This means that independent factors can act as external

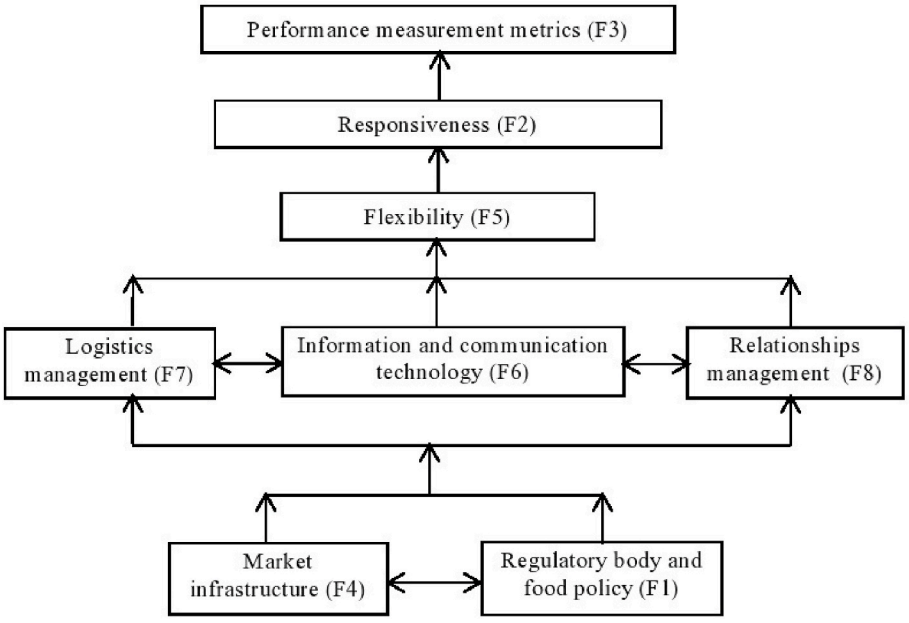

Fig. 2. ISM based hierarchical model of factors.

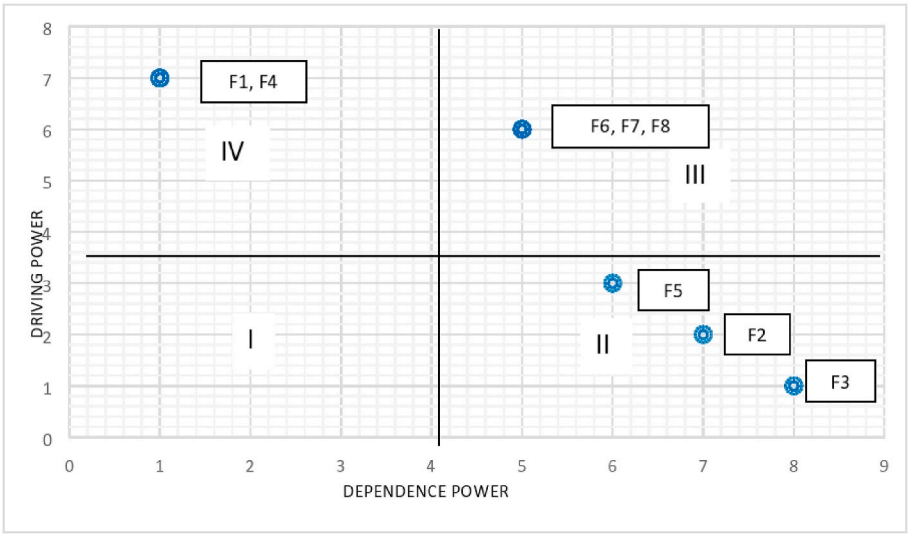

Fig. 3. Driving and dependence power of factors.

resources that will impact the internal resources (linkage factors) which in turn will improve the firm's performance (dependent factors). However, results of previous studies (Balaji and Arshinder, 2016; Gokarn and Thyagaraj, 2017; Kumar et al., 2020) do not show such relationships which can be justified by any established theories from the strategic point of view. Thus, this study meets the two broad requirements (i.e., comprehensiveness and parsimony) for judging the extent to which identified factors are representing the given phenomenon of interest.

6. Contribution

The findings of this study have a significant contribution. This empirical and interdisciplinary research contributes to the conduit of the integration of marketing and operations management literature-specifically, supply chain management literature. Additionally, this study focused on the entire FPSC rather than a particular supply chain echelon to identify, analyze, and categorize the factors necessary for the reduction of FLW in the Indian fresh produce industry.

This study incorporates theoretical and empirical perspectives in developing an understanding regarding the factors influencing the reduction of FLW in FPSCs. Prescriptive analytics (MCDM techniques) help in evaluating various factors to improve the efficiency and effectiveness of the decision-making process. Drawn on the prescriptive decision theory, the ISM-MICMAC method-an MCDM technique was used in this study to understand the structural relationships between identified factors and decide a course of action to prevent FLW in FPSCs. Thus, the application of an integrated research method (content analysis, ISM, and MICAMC) as a prescriptive technique in this study provides a guide for researchers on investigating driver-dependent relationships among representative factors in the given context.

The key findings of this empirical study extend the existing body of knowledge by answering the three aforementioned research questions in the introduction section. First, eight influencing factors are identified representing the given context from the literature under the purview of stakeholder theory, capabilities-based theory, and critical success factors theory as well as data collected through semi-structured interviews

from a group of selected experts. This study identifies performance-oriented factors such as flexibility, responsiveness, and PMM which contributes to the literature on the reduction of FLW in FPSCs. Moreover, previous studies have not identified the factors from the theoretical perspectives and considering entire FPSCs in a developing country like India. In answering the second research question, this study provides empirical evidence in the support of the key factors and simultaneously develops a structural model from the empirical perspective to uncover the potential interrelationships among the identified factors. This helps in answering the question of how the identified factors are interrelated. Finally, this study categorizes the factors into four different groups based on their driving and dependence power. Since research on this topic is still in its initial stages, this classification will help in further testing the hypothesized relationships.

This study also contributes to managerial implications significantly. The factors identified and selected in this research will help the practitioners/managers in understanding its influence and making short-term as-well-as long-term decisions related to the reduction of FLW in FPSCs in the context of developing countries like India. Factors responsible for the reduction of FLW are interrelated to each other across the FPSCs. Thus, practitioners/managers should not focus on each factor in isolation, preferably in an integration. A more comprehensive understanding of the influencing factors and interrelationships among them, through a logical structure, will support fresh produce firms to prioritize and effectively allocate their resources to reduce the FLW. Based on nature and impact, all key factors can be grouped among three levels, namely, macro-level, meso-level, and micro-level. Micro-level factors (performance measurement metrics, responsiveness, and flexibility) are limited to a particular stage of the FPSC, are performance-oriented, and will help in reducing FLW by taking actions in response to the external factors. Meso-level factors (logistic management, information technology and communication, and relationship management) can be found at the interface of two or more interlinked stages, and help in reducing FLW by sharing information and building trust between the partners of FPSC. Macro-level factors (Regulatory bodies and food policy and market infrastructure) are higher-level factors, related to the external environment, which will influence meso-level factors and which in turn will influence micro-level factors in reducing FLW in FPSCs.

For instance, at the macro-level, the Indian government makes a suitable policy to develop a structured market for improving the condition of infrastructure (e.g., investment in training programs) which in turn will influence the meso-level factors related to logistic management (e.g., trained loaders efficient in packaging and handling the produce) and in turn, it will improve the quality of loading at micro-level, which will help in reducing the FLW caused by poor loading. Kirezieva et al. (2013) highlighted that well-established rules and regulations and organized market infrastructure have an impact on the outcome of the supply chain. Imposing rules and regulations for certification, addressing quality and safety concerns, will influence the reduction of food waste (Balaji and Arshinder, 2016; Gokarn and Kuthambalayan, 2017). Government financial and non-financial support encourages fresh produce firms to take the initiative in improving their capabilities, which in turn helps in reducing FLW. Hence, in a developing country like India, also suggested by Hodges et al. (2010), the development of market infrastructure has the highest impact on the reduction of FLW across FPSCs.

In India, due to an inadequate level of market infrastructure for storage and transportation, food wastage is aggravated along the FPSCs (Kumar et al., 2020). Also, due to inefficient regulatory bodies and food policy, different actors of FPSC are incapable of taking curative measures to reduce FLW, reflecting a lack of sustainable responsibility (Gokarn and Thyagaraj, 2017). India is also facing an increase in urbanization and expansion in supermarket chains as in the industrialized countries. However, there is a lack of a competent regulatory body to frame food policies that empower farmers, promote small traders, favor cost efficiency and facilitate the participation of the private sectors which will help in the successful reduction in FLW in the long-term. Apart from this, food policies should also include issues related to safety and quality standards, research and development, capacity building, and development of infrastructure for practicing waste management to prevent FLW across the FPSCs. For the preservative of quality of fresh produce, the most vital aspect is temperature control. The absence of sufficient and efficient cold-chain infrastructure is a foremost contributor to FLW. For this, government should support building cold-chain and promote best practices at each stage of FPSC. For example, in certain cases if refrigerated vehicles are not available, insulated or covered vans could be suitable to prevent fresh produce losses. Besides, wholesalers should use plastic returnable containers as an alternative of plastic bags during transportation and storage of fresh produce which will significantly cut down the food losses.

Moreover, Policies for food waste prevention at the retailer and consumer level (downstream) should be informed immediately and effectively. Charging penalties from the supply chain actors who do not follow the rules and regulations or providing incentives in terms of fees, taxes, and subsidies to fresh produce firms for developing their capabilities will lead to more flexibility and responsiveness to the market which in turn will help to measure their performance in terms of quality and wastage. In the context of India, the government-a prime stakeholder at the center and state level, should play a proactive role in regulating laws and supporting policies along with resources. Thus, rules and policies made by regulatory bodies related to the fresh produce industry put more pressure on improving the capabilities of a firm which in turn will help in reducing FLW across FPSCs in India. For instance, due to industrial pressure, the Indian government has allowed 100 percent FDI in the food processing industry, which has made an easy entry for multinational corporations (from developed countries), and to procure fresh produce from India. Due to this, multinational corporations will bring efficient machines for food processing, new information technology for tracking the products in storage and transit, and managerial skills for the successful flow of information, money, and produce along with capital. They will also develop a good relationship with their suppliers to procure the produce by having a formal contract with them. Hence, these activities will affect in minimizing the uncertainty in terms of supply and demand, resulting in less wastage, which in turn will help in improving the trust between them. Thus, the entrance of multinational corporations in developing countries, like India, will help the small fresh produce firms to strengthen their resources and capabilities, which in turn enables them to take sustainable initiatives to reduce FLW across the FPSCs. Moreover, it is a difficult task to motivate skilled, well-paid, and trained workers to work in rural areas for a more extended period. Hence, regulatory bodies should provide specific preferential policies or incentive for the firms which want to work in the Indian fresh produce industry.

Fresh produce industry in India is fragmented and lacks competence (Joshi et al., 2009; Gokarn and Kuthambalayan, 2017). It is inefficient in terms of its information technology, logistics, and relational capabilities. An increase in a firm's capabilities will facilitate closer coordination between production and distribution activities and reduces supply chain risk and uncertainty responsible for FLW across the FPSCs. ICT plays a significant role in reducing FLW in Indian FPSCs. The sharing of proper information on time will reduce forecasting error, which in turn will help in reducing FLW across FPSCs. Disruptive technology such as (IoT, big data analytics, blockchain technology, and artificial intelligence, etc.) can be used to create a mobile-based system that can be used by each supply chain actor to reduce the supply chain uncertainty (price, supply, and demand uncertainty) which in turn will help in reducing FLW significantly at each stage. For example, tomato, a kind of fresh produce in India experiences large price variation due to asymmetrical information and lack of coordination among supply chain actors (Sharma et al., 2019). Easy access to the Internet in India can play a crucial role in sharing the information among different stakeholders of the FPSCs. A mobile application can be a platform to share information

regarding order placement, FLW awareness campaign, and redistribution of the surplus produce, which will help in reducing FLW across the FPSCs. However, Indian farmers are somewhat reluctant to ICT to share information related to fresh produce. This may be because they rely on their experience for farming rather than technology. One reason for this can be that farmers are generally unskilled and untrained. Regulatory bodies and firms should take initiatives to educate and train them for using ICT as a means for sharing information, which will help in minimizing the bull-whip effect which in turn will help in the reduction of FLW. In contrast, in developed countries, farmers have started to take advantage of ICT in reducing FLW. Supply chain actors having strategic collaboration shall provide efficient resources and create cognizance regarding the positive impact of ICT over perishability which in turn will help in reducing FLW.

Policies to encourage more distributed production of fresh produce will reduce the need for transportation hence helping in reducing FLW at storage and transportation process at each level by decreasing the food miles. Moreover, small fresh produce firms should cooperate to establish an association to tackle the capital investment constraints in the fresh produce industry. They should be flexible in terms of delivering fresh produce to the extra point of sale, and additional volume orders that will help in minimizing the wastage. Flexibility, supported by efficient firms' capabilities (logistic capabilities, information technology capabilities, and relational capabilities) is essential in the fresh produce industry to enhance the responsiveness to meet the customer's request in a given time frame, which will help in overtaking the perishable constrain and hence minimizing the wastage. In the case of India, the creation of 'local' and 'shorter' supply chain networks can be more flexible and responsive to lead time, delivery location, and product volume changes, which will result in the reduction of FLW.

To address FLW at each stage of FPSC, a combination of policies and institutions along with a favorable environment that enables the coordination and collaboration among different actors and stakeholders is required. Moreover, it requires policy reforms, innovative technology, and managerial skills to strengthen fresh produce firms. Thus, the ability to build and manage the capabilities and devise efficient supply chain networks are generally controlled and dependent on regulatory bodies and food policy, and market infrastructure. Any positive change in policy and regulation related to fresh produce is leveraged by the firms' capabilities to improve the flexibility and responsiveness of the FPSC, which in turn will improve the performance in terms of FLW reduction across the FPSCs in India. Moreover, the classification of the factors will also help FPSC managers and policymakers reducing FLW. FPSC managers can easily differentiate the factors into different groups based on their driving–dependence power and understand the dynamics of the relationships between each group category. This will help in formulating the strategies to leverage the impact of independent factors by developing different types of capabilities (linkage factors), which will improve dependent factors significantly. Furthermore, this knowledge will help in framing policies and making strategic decisions for managing the resources and capabilities which in turn will help in reducing FLW across FPSCs and attaining SDGs (Target 12.3).

7. Conclusion and directions for future research

Drawing upon the literature of FPSCM under the purview of management theories (namely, stakeholder theory, capabilities-based theory, and critical success factors theory), this study developed a theoretically grounded framework by identifying influencing key factors and establishing interrelationships between them for the reduction of FLW in the Indian FPSCs.

In the pursuit of finding the answer to the research questions related to the successful reduction of FLW in FPSCs in the Indian context (developing countries), this paper has identified eight influencing key factors based on literature review under the purview of management theories and through semi-structured interviews with experts. Further, based on the responses taken from the experts, an integrated hierarchal model is developed to uncover the interrelationships among the factors for the given context. Finally, these key factors are classified into four different groups of two-dimensional (driving-power/dependence-power) diagrams which will help in understanding their nature and role in implementing sustainable practices to reduce FLW in FPSCs. The factor regulatory bodies and food policy (F1) and market infrastructure (F4) are determined as the most significant factors whose substantial advantages will be realized in promoting sustainable practices to reduce FLW in FPSCs.

The findings of this study provide a valuable reference in reducing FLW across the FPSC in developing countries like India. Moreover, the categorization of these factors provides essential information to decision-makers in giving priority to the key factors in accordance with their interrelationships in the given context. In the case of FPSCs, managers generally focus on one or two factors that they consider more significant without considering the impact of other factors in the given context. The relative importance of key factors influencing the reduction of FLW in FPSCs must be considered while making decisions. Furthermore, the dynamics of the relationship among the influencing factors will give insights for understanding the importance of factors and framing the policies, regulations, and making strategic decisions for the reduction of FLW in FPSCs. Understanding the hierarchy of the structured model will guide the practitioners in uncovering the micro (performance-oriented factors), meso (internal factors), and macro (external factors) level interrelated impacts of the key factors in reducing FLW in FPSCs. Thus, the outcomes of this study such as ISM based model (Fig. 2) and MICMAC diagram (Fig. 3) will help all the stakeholders of the FPSC in reducing FLW by addressing the key factors effectively which in turn will help in achieving SDGs (target 12.3). This study also provides essential information to the academicians to relate these factors to other issues related to the sustainable FPSC and reduction of FLW. Since the same situation of FLW exists in most developing countries, as in the case of India, a similar set of solutions can be implanted in those countries. Moreover, these findings will also be useful for the fresh produce firms that are operating or planning to operate FPSCs in developing countries, particularly India.

In this study, data is collected from the experts in developing an ISM-based model and applying MICMAC analysis. As these inputs are subjective and based on the judgment of the experts, there are chances of biases that might have influenced the final result. This can be mitigated by collecting data from relevant respondents through a questionnaire-based survey and applying exploratory factor analysis (EFA) as a statistical technique for grouping similar factors into a super-set factor. In this study, all eight factors are categorized into four categories, but the strength of their relationship is not measured. A statistical tool or operational tool may be used to measure the power of the relationships and validate the results. The dynamics of the intra-relationships between the factors of each category are not studied in this paper, which can be studied in future research. ISM-based model is not statistically validated, so other approaches such as structural equation modeling (SEM) can be applied to test the validity of this model. However, it is essential to highlight, although SEM has the capability of validating an existing theoretical model, it cannot help in developing an initial structured model. In contrast, ISM is used to transform a poorly articulated model of the system into a well-structured hierarchy model.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A: List of representative factors influencing FLW in FPSCs

Factors	Description
Regulatory bodies and food policy	It refers to regulating food industry behaviors, such as marketing unhealthy foods and promoting purchases in large portions, which contribute to poor diet and waste.
Responsiveness	It refers to the ability of the fresh produce supply chain to respond firmly and within a suitable timeframe to customer requests or order to reduce food waste.
Performance measurement metrics	It is a set of parameters that enable a fresh produce firm to measure the respective performance indicators related to the respective functions in a given time frame.
Market infrastructure	It refers to essential facilities required for cost-effective marketing, to minimize post-harvest food waste and loss, and to reduce health risks.
Government support	It refers to support given by the government to businesses both financially, in the form of grants, and through access to expert advice, information and services.
Flexibility	It refers to the capability in which the supply chain of a fresh produce firm responds to cope with changes in demand and the business environment to reduce the uncertainty causing food waste
Information and communication technology	It refers to all the technology used to share the flow of information across the fresh produce supply chain to meet the customer's order.
Logistics management	It helps in meeting customer demands through the planning, control, and implementation of the operative movement and storage of fresh produce from the point of origin to the point of consumption.
Relationship management	It is the extent to which a fresh produce firm manages the relational activity of its supply chain partners to improve its performance in terms of reduction in food loss and waste.
Consumer behaviour	It refers to the way an individuals or organizations purchase and consume fresh produce.

Credit author statement

Samir Gokarn: Conceptualization, Methodology, Software, Formal analysis, Writing, Reviewing and Editing, Aparna Choudhary: Methodology, Validation, Writing, Reviewing and Editing

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