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Developing a Service Management Framework in the Agricultural Supply Chain with Fuzzy Weighted Average

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Abstract

The main objective of this research is to create a comprehensive and adaptable framework for assessing performance in agricultural supply chains and develop two improving approaches. The most relevant performance measures are selected to assess the current status of services in agricultural supply chains (ASCs). The contribution of this research is related to the selection of key performance indicators (KPIs) and approaches for enhancing ASC performance. The proposed framework comprises performance measurement and a service selection process. Two approaches have been developed based on the selected KPIs of services in ASC to identify which services require improvement. The proposed approaches are robust and versatile tools for agricultural managers to strategize and enhance their supply chains. A case study is also presented from Iran. For this region, selection approaches prioritize agricultural services such as postproduction consulting, financial support, mechanization, business consulting, and input supply. The framework shows that these services should be improved in order to better meet the needs of the region under study.

Keywords: Agriculture, Fuzzy, Performance measure, Service, Supply chain

Introduction

The term "agricultural supply chains" (ASC) refers to some activities involved in bringing agricultural or horticultural products from the farm to the table, including production, distribution, and marketing (Aramyan, Ondersteijn, Kooten, & Lansink, 2006). The ASC has recently received considerable attention due to emerging public health concerns. It has become apparent that in the near future, the design and operation of ASCs will be subject to more stringent regulations and closer monitoring, especially for products intended for human consumption, such as agrifoods (Ahumada & Villalobos, 2009). Designing agrifood supply chain (SC) networks becomes more challenging when sustainability is incorporated into the traditional economic oriented models (Allaoui, Guo, Choudhary, & Bloemhof, 2018). The literature highlights the growing interest in developing agricultural supply chain performance management frameworks using operation research methods. These studies emphasize the need for comprehensive evaluation methods that consider various criteria such as cost, quality, delivery, sustainability, and flexibility. Different studies integrated the techniques like fuzzy logic, Fuzzy Delphi, AHP, PROMETHEE, and MCDM, offering effective decision-making support and aids in developing optimized agricultural supply chains.

van der Vorst, Peeters, and Bloemhof

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(2013) presented a sustainability research framework for food supply chains logistics including drivers, strategies, performance, and indicators. The study provides insights into the development of a sustainability assessment framework for food supply chain logistics. Routroy and Behera (2017) provided a comprehensive review of literature on the agriculture supply chain. Rehman, Al-Zabidi, AlKahtani, Umer and Usmani (2020) used a fuzzy multicriteria method to assess the agility of a supply chain. While it does not focus on agricultural supply chains, it provides insights into the use of fuzzy logic for evaluating supply chain performance. Oubrahim, Sefiani, and Happonen (2022) presented a review of supply chain performance evaluation models. It provides insights into the different methods and models used for evaluating supply chain performance. Evangelista, Aro, Selerio, and Pascual (2023) proposed an integrated Fermatean fuzzy multiattribute evaluation method for evaluating digital technologies for circular public sector supply chains. Thumrongvut, Sethanan, Pitakaso, Jamrus, and Golinska-Dawson (2022) addressed the problem of designing tourist trips and planning tour routes to improve the competitiveness of community tourism. The study proposed the use of Industry 3.5 approach for planning more sustainable supply chain operations for tourism service providers. Banaeian, Zangeneh, and Golinska-Dawson (2022) proposed a multicriteria sustainability performance assessment of horticultural crops using Data Envelopment Analysis (DEA) and Elimination and Choice Translating Reality IV (ELECTRE IV) methods. The study aimed to evaluate the sustainability performance of horticultural crops and identify the most sustainable crops. These studies provide insights into the sustainability of agricultural production and supply chains and propose frameworks and approaches for achieving sustainability goals.

Generally, there are three types of commodities in the agricultural sector: (1) farm based commodities, (2) animal commodities, and (3) natural resource commodities. Each commodity requires various services, which can be categorized as follows: (a) input supply services, (b) consulting services, (c) business services, and (d) technical services. In this study, we focus on commodities and services that are based on farms.

In the context of the ASC, four main functional areas are identified: production, harvest, storage, and distribution (Ahumada & Villalobos, 2009). The subservices within each service type were identified by analyzing the activities of agricultural service companies in multiple countries. Consulting services are available in both the production and postproduction phases.

Literature review

Challenges of ASC

Farmers around the world face numerous constraints, such as limited access to financing, inputs, and technologies, which hinder their ability to improve production (Graham, Kaboli, Sridharan, & Taleghani, 2012). The challenges of ASC can be managed through different levels of management practices, including strategic, tactical, and operational approaches. In this study, we consider the strategic challenges that are almost exclusively related to services in ASCs. To focus the research, a summary of challenges mentioned in the literature will serve as a frame. This summary is presented in Table 1. Recently, most of the current research has focused on improving individual firms or processes rather than designing an entire supply chain (Allaoui *et al.*, 2018). In the current study, a smart service management procedure is being investigated.

Ganeshkumar, Pachayappan, and Madanmohan (2017) presented a critical review of prior literature relating to agrifood supply chain management. The study identifies gaps to be explored about agricultural supply chain management practices and provides a comprehensive understanding of the different aspects of agricultural supply chains.

Despoudi, Spanaki, Rodriguez-Espindola, and Zamani (2021) suggested a framework for achieving sustainability in agricultural supply chains using Industry 4.0 technologies. The study provides insights into the challenges and opportunities for achieving sustainability goals in agricultural supply chains. Singh, Biswas, and Banerjee (2023) used bibliometric analysis tools to identify obstacles in the agricultural supply chain and proposes future directions for research. Morkūnas, Rudienė, and Ostenda (2022) investigated the potential of climate-smart agriculture to enhance food security through short supply chains. The literature review suggests that achieving sustainability in agricultural supply chains and services is an important area of research. The use of Industry 4.0 technologies and climate-smart agriculture are emerging areas that can help achieve sustainability goals in agricultural supply chains.

Table 1- Challenges of ASC

Subject	Challenges	Reference
Rice Supply Chain in Iran	Damages from pesticides and fertilizers, price, demand, permissible cultivation area, guaranteed purchase of government, and direct sales of farmers	(Kazemi & Samouei, 2024)
Rice Supply Chain in Iran	Total profit, integrating different decisions of the rice supply chain, including supplier selection, cropping, fertilizing, pest control, harvesting, milling, transportation, and distribution	(Jifroudi *et al.*, 2020)
Organic Agri-Products SC in Iran	lack of direct communication or online communication platform to communicate with customers, and lack of procedure for collecting and documenting information	(Ghazinoori, Olfat, Soofi, & Ahadi, 2020)
Shea in Africa	Labor shortage, poor storage, suboptimal postharvest processing, the lake of access to financing, low adaptation of grafting, absence of effective controls and sorting processes, and low awareness among international buyers	(Graham *et al.*, 2012)
Palm oil in Africa	Low access to reliable market information, trade –offs between food and cash crop production, access to financing, low productivity and quality from smallholder farmers, lack of access to processing mills, certification adherence, and environmental issues	(Graham *et al.*, 2012)
Cashew in Africa	Poor seed/tree stock, lack of fertilizer and pesticides, little weeding, limited labor for fruit picking, lack of certification/standards, poor postharvest, poor grading techniques, and bad marketing	(Graham *et al.*, 2012)
Food distribution	Low profit margins, food safety, food quality, and sustainability	(Akkerman, Farahani, & Grunow, 2010)
Food SC in Europe	Design and development of ICT solutions and expert systems and decision support systems to support decisions on the strategic planning of land use, facilities sites, and operation management within a food SC	(Manzini & Accorsi, 2013)

Performance measurement in ASC

Various perspectives can be found in the literature for evaluating the performance of supply chains (SCs). The evaluation of service center performance in service delivery can be complex and may vary even within the same sector (Cho *et al.*, 2012). Numerous techniques, encompassing both qualitative and quantitative approaches, are discussed in the literature pertaining to the service sector (Buyukozkan, Cifci, & Guleryuz, 2011). These selection models include both statistical and decision theory models. For instance, Chang, Hung, Wong, and Lee (2013) focused on constructing and implementing SCs to determine ways to overcome SC barriers and evaluate SC integration performance using the balanced scorecard approach. Vorst (2005) proposed a framework for developing innovative food supply chain networks and discussed the implications of implementing a performance measurement system and addressing respective bottlenecks. Aramyan *et al.* (2006) developed a conceptual framework for the existing performance indicators in ASC. These indicators are classified into four primary categories: efficiency, flexibility, responsiveness, and food quality. Each category includes more specific performance indicators.

Improving the performance of agricultural supply chains requires comprehensive approaches that include performance evaluation systems, metrics, responsible guidelines, and advanced analytics. The proposed frameworks and approaches can help agricultural managers to make informed decisions to improve the sustainability and smartness of their supply chains. Trivellas, Malindretos, and Reklitis (2020) conducted a study on the implications of green logistics management on sustainable business and supply chain performance in the Greek agrifood sector. The study also proposed a conceptual framework for understanding the relationship between green logistics management and sustainable performance. Zangeneh, Nielsen, Akram and Keyhani (2014) proposed a performance evaluation system for agricultural services in supply chains. The study compares all possible scenarios to improve the performance of agricultural supply chains. Ramos, Coles, Chavez, and Hazen (2022) suggested metrics for measuring agrifood supply chain performance. The study provides insights into the factors that can improve supply chain performance in the agricultural sector.

Despite the importance of supply chain management (SCM), only a few researches have focused on the services it offers (Sengupta, Heiser, & Koll, 2006; Baltacioglu, Ada, Kaplan, Yurt, & Kaplan, 2007; Ellram, Tate, & Billington, 2007; Buyukozkan *et al.*, 2011; Cho, Lee, Ahn, & Hwang, 2012). Several studies emphasize the improvement of supply chain performance (Joshi, Banwet, Shankar, & Gandhi, 2012; Uysal, 2012; Cho *et al.*, 2012). Ulutas, Shukla, Kiridena, and Gibson (2016) proposed an integrated solution framework that can be used to evaluate both tangible and intangible attributes of potential suppliers in supply chains. This framework combines three individual methods: the Fuzzy Analytic Hierarchy Process, Fuzzy Complex Proportional Assessment, and Fuzzy Linear Programming. According to the literature, a comprehensive approach is necessary to identify and prioritize relevant criteria for developing a systematic performance measurement process for SCM.

While there are few research works specifically focused on this topic, insights from related fields suggest that fuzzy logic can be a valuable tool for evaluating supply chain performance. Generally, the literature suggests that incorporating smart and sustainable practices in agricultural supply chains is essential for achieving sustainable and efficient agricultural services. The proposed framework and approaches for improving the performance of agricultural services in supply chains can be used by agricultural managers to enhance the sustainability and competitiveness of their supply chains.

In this study, we propose a portfolio of agricultural services aimed at improving the overall performance of ASC. The goals of providing services in an ASC should be defined based on the ASC's objectives. In this study, we considered the following goals for service supply that influence the ASC targets: (1) Optimize the service delivery performance, including service order lead time and customer query time, (2) Minimize the service cost, including cost paid by customers to receive the services, (3) Maximize the service quality, view point of technical, health and environmental aspects, and (4) Maximize the service flexibility, including innovation, reflect customer needs etc.

Materials and Methods

Performance measures for services in ASC

In this section, we present a framework for performance measures and metrics to investigate the current status of services implemented in ASC for farm based commodities, including farming and horticulture (Table 2).

Table 2- Framework of KPIs of services in ASC

Production phase	Type of Service	Performance measures	#PM	References
Preproduction (PP)	1. Input supply (PP1)	Supplier's delivery performance (on time delivery and delivery reliability performance)	PM1	(Gunasekaran, Patel, & McGaughey, 2004)
		Supplier's pricing against market	PM2	(Gunasekaran *et al.* 2004)
		Quality of supplier's inputs	PM3	(Mapes, New, & Szwejczewski, 1997)
		Supplier's auxiliary services (booking, cash flow method, purchase order cycle time, and back order)	PM4	(Gunasekaran *et al.* 2004)
Production (PR)	1. Mechanization services (PR1)	Quality of services	PM5	(Mapes *et al.*, 1997)
		Customer query time	PM6	(Bigliardi & Bottani, 2010)
		Service pricing against market	PM7	(Gunasekaran *et al.*, 2004)
	2. Consulting services (PR2)	Customer satisfaction	PM8	(Aramyan *et al.*, 2006)
		The flexibility of services to meet customer needs	PM9	(Gunasekaran *et al.*, 2004)
	3. Financial services (PR3)	Customer query time	PM10	(Bigliardi & Bottani, 2010)
		The flexibility of services to meet customer needs	PM11	(Gunasekaran, Patel, *et al.* 2004)
Post production (PO)	1. Consulting services (PO1)	Customer satisfaction	PM12	(Aramyan *et al.*, 2006)
		The flexibility of service systems to meet customer needs	PM13	(Gunasekaran *et al.*, 2004)
	2. Inspection services (PO2)	Customer query time	PM14	(Bigliardi & Bottani, 2010)
		Reliability of performance	PM15	(Bhagwat & Sharma, 2007)
	3. Business services (PO3)	Purchase order cycle time	PM16	(Bhagwat & Sharma, 2007)
		Shipping errors	PM17	(Aramyan *et al.*, 2006)
		Service pricing against market	PM18	(Gunasekaran *et al.*, 2004)

Proposed approaches to select best alternatives to improve the ASC performance

There are a total of seven types of services available in ASCs. The combination of these services forms alternatives for improving ASCs. In this research, substituting the current service suppliers with new service centers that offer better services is considered an improvement action. Making decisions to choose an alternative that can enhance performance measures and improve the main targets of ASC is very difficult due to the complex relationships and inherent complexity of services in SCs. Therefore, an effective procedure is needed to select the best agricultural services alternatives. There are several scenarios which can improve the performance of agricultural services in ASC. Scenario I offers the most services, while scenario 4 offers the least. In the first scenario, all services are distributed in the region through service centers, but budget and time constraints make this impossible. This scenario may lead to short term economic losses because the older service providers in the region have more competitive capabilities than the new service center. In the long term, if the service center's performance and quality of services exceed those of its competitors and satisfy its customers, the center may consider adding additional services to its service package. Therefore, the first scenario does not meet the aims of our research and will be disregarded. The fourth scenario considers services that are deemed necessary in the region based on the performance measure survey and have the greatest impact on ASC performance. As this scenario overlooks the necessary services in the region, it should only be considered when managers are under tight budget and time constraints and must choose the most efficient services from the required ones. This type of scenario will not be investigated in the current study.

This research focuses on Scenario II, and two different approaches have been designed to evaluate this scenario. To begin, an integrated algorithm must be designed. Next, thresholds for performance measures of service types should be determined in order to select the best service packages as alternatives to improve the overall performance of the supply chain. Strategic level managers can specify the threshold for each performance measure. If the value of a performance measure for a service falls below/above the threshold (based on whether the character should be maximized or minimized), then another service supplier should implement that service in the supply chain. The next section describes the formulation of the service selection procedure based on the relevant performance measurements.

First approach: Fuzzy Weighted Average (FWA)

The first approach for evaluating the PM and proposing improvement actions uses FWA. Some definitions of fuzzy numbers, the fuzzy pairwise comparison, has been illustrated completely in several kinds of literature (Zimmermann, 2001; Wu, Pu, Shao, & Fang, 2004); Zadeh, 1965; Cho *et al.*, 2012; Zheng, Zhu, Tian, Chen, & Sun, 2012)). The concept of FWA and related formulas are described in the following section. The Fuzzy Weighted Average (FWAs) (Dong & Wong,1987; Liou & Wang,1992) is a process that may be defined as whereby via obtaining the fuzzy ratings A_{ji} of some objects S_j with respect to a set of criteria, attributes or factors $i \in \{1,2,\ldots,n\}$ of a problem. Also, the fuzzy weighting or importance of the criteria, W_i, $i \in \{1,2,\ldots,n\}$, reaches the objective function that aggregates the fuzzy ratings of the objects S_j and the fuzzy weights into the fuzzy aggregated outcomes M_j. The linguistic variables and related trapezoidal fuzzy numbers for both fuzzy weighting and fuzzy rating are given in Tables 3 and 4, respectively. Relich & Pawlewski (2017) used FWA to assist managers in making portfolio selection decisions for ranking new product projects and artificial neural networks for estimating project performance.

Table 3- Scale of relative importance of performance measurements of each service type

The scale of the relative importance	Trapezoidal fuzzy number	Linguistic variable
1	(1,1,1,1)	Equally important
3	(2, 2.5, 3.5, 4)	Weakly important
5	(4, 4.5, 5.5, 6)	Essentially important
7	(6, 6.5, 7.5, 8)	Very strongly important
9	(8, 8.5, 9, 9)	Absolutely important

Table 4- Linguistic variable and trapezoidal fuzzy numbers for the evaluation of each PM in the studied region

Scale of evaluation	Trapezoidal fuzzy number	Linguistic variable
1	(0,0.1,0.2,0.3)	Very poor
3	(0.1,0.2,0.3,0.4)	Poor
5	(0.3,0.4,0.5,0.6)	Medium
7	(0.5,0.6,0.7,0.8)	Good
9	(0.7,0.8,0.9,1.0)	Very good

Therefore, FWAs serve as an aggregation process for multiple criteria decision-making problems. Objects can be ranked using a ranking method based on their outcomes. Thus, an FWA can be defined as a system that includes both fuzzy criteria ratings and fuzzy weightings (Cho *et al.*, 2012; Chang, Hung, Lin, & Chang, 2006). More information about the efficient fuzzy weighted average can be found in the publication by Chang, Lee, Hung, Tsai, and Perng (2009).

Second approach for selecting agricultural services

In this paper, a multistep procedure has been developed to investigate the performance measurement of ASSC and improve the ASC's performance. This approach comprises three main steps. The first two steps involve studying the current situation of ASC, while the last step focuses on improving ASC. A schematic diagram of the approach developed in this research is presented in Figure 1.

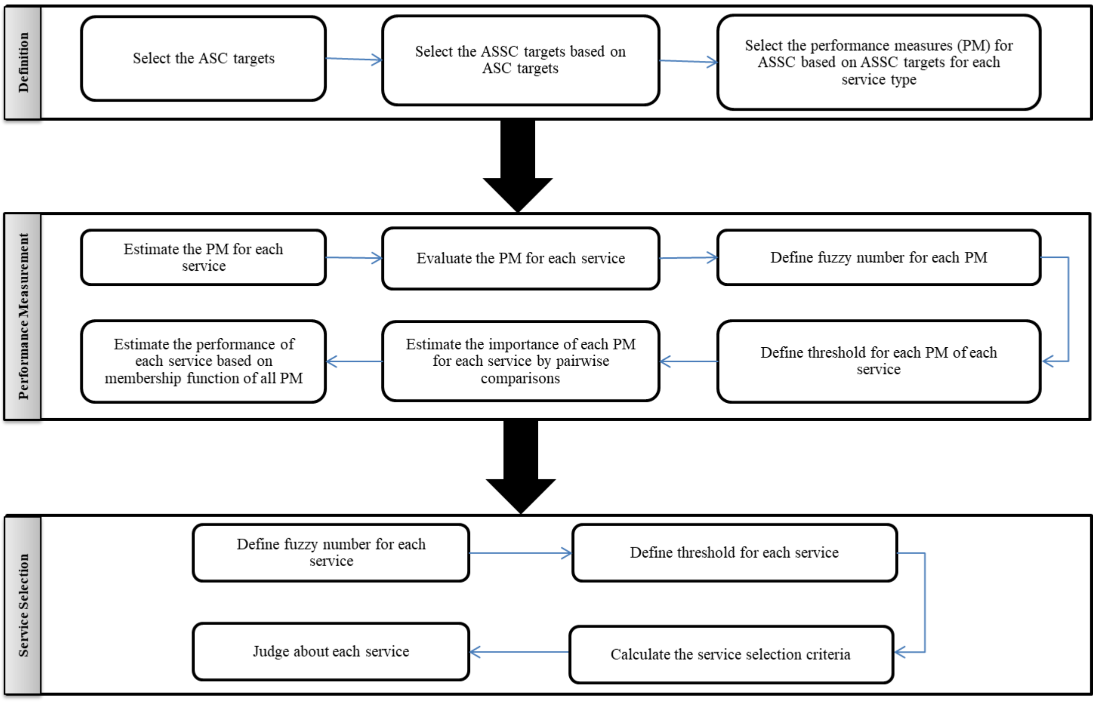

Fig.1. The summary of the second service selection approach

The proposed approach utilizes the fuzzy decision process. This is because when the estimation of a system coefficient is imprecise and only vague knowledge about the actual value of the parameters is available, it may be convenient to represent some or all of them with fuzzy numbers (Zadeh, 1965). The use of fuzzy theory in analyzing supply chains is relevant due to the inherent characteristics of this field. For instance, Mangla *et al.* (2018) employed a combined framework of Interpretive Structural Modeling (ISM) and fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) to analyze the factors that enable sustainability in agrifood supply chains. The desirability of each service performance measurement is represented as a unique left trapezoidal (or right trapezoidal) fuzzy number. The left trapezoidal numbers are used for performance measurement when a lower value is preferred, while the right trapezoidal numbers are used when a higher value is preferred. In other words, a higher value of the membership function for a PM indicates a higher level of undesirability for that PM. For example, a value of 1 indicates that the PM is highly undesirable. If the membership function for service performance measurement is lower/higher than the threshold for the left and right fuzzy numbers, then the service can be considered as an option for improving performance. The value of the membership function and the relative importance of all performance metrics for each service type is used to determine the worst service viewpoint based on their performance.

These services will be selected for distribution by service centers to improve the quality of service in the region. The proposed selection procedure is formulated as equation (1):

$$A_i = \sum_{j=1}^{m} w_{ij} X_{ij} \quad \forall i \qquad (1)$$

Where parameters: w_{ij}, X_{ij} are:

$\sum_{j=1}^{m} w_{ij} = 1 \quad \forall i \qquad 0 \le w_{ij} \le 1$

The value of w_{ij} for performance measurement, j of service i will be estimated using pairwise comparison survey between the performance measurements of service i.

X_{ij}: The membership function value of performance measurement j of service i.

Indices: i, j

i: The index of services $i = 1,2, \ldots, n$.

j: The index of performance measurement $j = 1,2, \ldots, m$. $\qquad 0 \le w_{ij} X_{ij} \le 1$

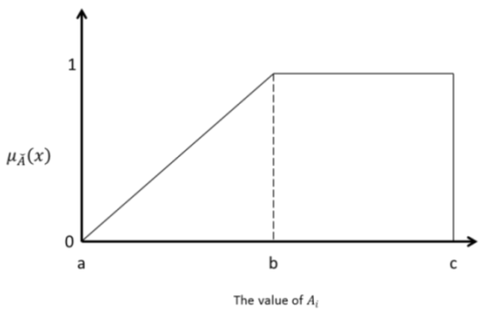

Fig.2. Left trapezoidal Fuzzy number for the A_i

Using the proposed procedure, the service i will be selected to import the service center if the value of $A_i = w_{ij} X_{ij}$ is greater than b (b is a threshold for service i), otherwise, it will not be selected. The left trapezoidal fuzzy number (Fig. 2) is selected here to select the worst services, because A_i was calculated using X_{ij} and a bigger value of X_{ij} indicates more membership degree to the undesirable service set. So whenever A_i is bigger, the chance of service i being selected will increase. So an algorithm is developed to choose which services must be imported to the service center, to create the solution space (Fig.3).

The framework proposed in this paper is a preliminary step towards improving the performance of ASC. After designing the best service packages, a crucial issue is their distribution to evaluate their effectiveness.

The required data for running the developed framework for selecting services is estimated according to the characteristics of the studied region via local database and interviews with farmers.

Results and Discussion

A case study is presented to demonstrate the application of the methodology for resolving ASC performance issues. The region under study is Razan, a county situated in the northern part of Hamedan province in Iran.

Table 5 presents the efficiency criteria values for the studied region, which were derived from local databases and interviews with farmers from the area. The value of each performance measure indicates the current status of that measure in the agricultural supply chain of the region. This criterion can take a value between zero and 100. In each criterion, a larger number indicates a better situation for positive criteria and a worse situation for negative criteria in terms of the efficiency of that service. For example, the number 40, concerning the input supplier's delivery efficiency criterion (PM1) as a negative criterion, whose fuzzy number is of the left type, indicates the relatively good condition of the input suppliers in the region. The higher this number is, the worse the supply services in the region will be. On the other hand, there are criteria that determine whether the type of fuzzy number associated with them is appropriate. The higher these criteria are, the better the performance. For example, the value of the input quality criterion (PM3) as a positive criterion is equal to 30. By referring to its fuzzy number, it can be concluded that the quality of the input provided in the studied region is not optimal and there is a need to review and correct it. The values of other performance criteria can be judged similarly.

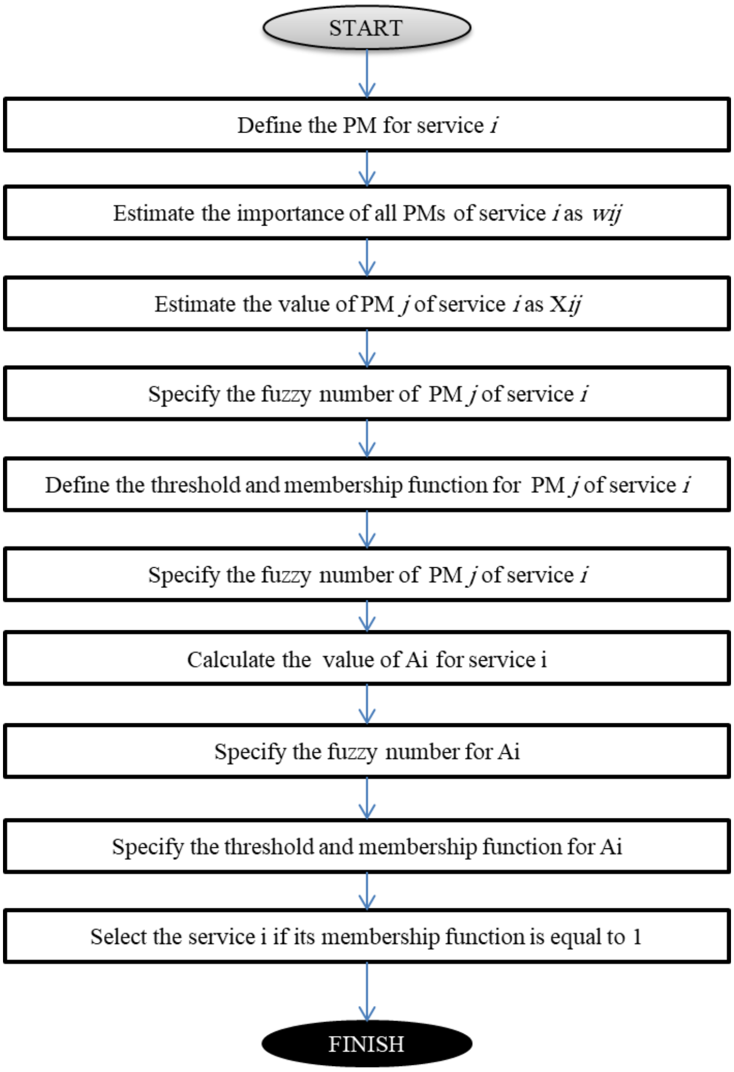

Fig.3. The service selection procedure

Table 5- The value of agricultural supply chain efficiency indicators in the study area

Service	**PP1**					**PR1**			**PR2**	**PR3**		**PO1**		**PO2**		**PO3**		
#PM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Value	40	60	30	50	70	100	40	70	10	30	60	70	80	100	60	40	20	50

FWA procedure results

The FWA procedure requires determining the fuzzy weights of decision criteria (performance measurements) and decision objects (service types). The fuzzy numbers resulting from the PMs' pairwise comparisons are obtained and represented as a vector of fuzzy weights for each service type in Table 6. The results of the fuzzy weight calculation are shown in Table 7, and these values can be applied to other case studies. The values of the fuzzy rating in each case study vary. Therefore, we utilized the proposed approach to demonstrate its computation details and results for a region in Iran.

Table 6- Pairwise comparison matrix of the PMs

PP1	CI	PM1	PM2	PM3	PM4
PM1	0.1	$(1,1,1,1)$	$(2, 2.5, 3.5, 4)$	$(8, 8.5, 9, 9)^{-1}$	$(2, 2.5, 3.5, 4)$
PM2		$(2, 2.5, 3.5, 4)^{-1}$	$(1,1,1,1)$	$(6, 6.5, 7.5, 8)^{-1}$	$(2, 2.5, 3.5, 4)$
PM3		$(8, 8.5, 9, 9)$	$(6, 6.5, 7.5, 8)$	$(1,1,1,1)$	$(8, 8.5, 9, 9)$
PM4		$(2, 2.5, 3.5, 4)^{-1}$	$(2, 2.5, 3.5, 4)^{-1}$	$(8, 8.5, 9, 9)^{-1}$	$(1,1,1,1)$
PR1		PM5	PM6	PM7	
PM5	0.09	$(1,1,1,1)$	$(6, 6.5, 7.5, 8)$	$(8, 8.5, 9, 9)$	
PM6		$(6, 6.5, 7.5, 8)^{-1}$	$(1,1,1,1)$	$(4, 4.5, 5.5, 6)$	
PM7		$(8, 8.5, 9, 9)^{-1}$	$(4, 4.5, 5.5, 6)^{-1}$	$(1,1,1,1)$	
PR2		PM8	PM9		
PM8	0.00	$(1,1,1,1)$	$(8, 8.5, 9, 9)$		
PM9		$(8, 8.5, 9, 9)^{-1}$	$(1,1,1,1)$		
PR3		PM10	PM11		
PM10	0.00	$(1,1,1,1)$	$(6, 6.5, 7.5, 8)$		
PM11		$(6, 6.5, 7.5, 8)^{-1}$	$(1,1,1,1)$		
PO1		PM12	PM13		
PM12	0.00	$(1,1,1,1)$	$(6, 6.5, 7.5, 8)$		
PM13		$(6, 6.5, 7.5, 8)^{-1}$	$(1,1,1,1)$		
PO2		PM14	PM15		
PM14	0.00	$(1,1,1,1)$	$(8, 8.5, 9, 9)^{-1}$		
PM15		$(8, 8.5, 9, 9)$	$(1,1,1,1)$		
PO3		PM16	PM17	PM18	
PM16	0.08	$(1,1,1,1)$	$(8, 8.5, 9, 9)$	$(6, 6.5, 7.5, 8)$	
PM17		$(8, 8.5, 9, 9)^{-1}$	$(1,1,1,1)$	$(2, 2.5, 3.5, 4)$	
PM18		$(6, 6.5, 7.5, 8)^{-1}$	$(2, 2.5, 3.5, 4)^{-1}$	$(1,1,1,1)$	

Table 7- Evaluated performance measurement of the services and related αcut ($\alpha = 0.5$)

#PM	**PM importance**			**Service evaluation**		
	Fuzzy weight	αcut value		Fuzzy rating	αcut value	
PM1	(0.11,0.13,0.17,0.20)	0.12	0.185	(0.3,0.4,0.5,0.6)	0.35	0.55
PM2	(0.07,0.08,0.11,0.13)	0.075	0.12	(0,0.1,0.2,0.3)	0.05	0.25
PM3	(0.60,0.65,0.77,0.84)	0.625	0.805	(0,0.1,0.2,0.3)	0.05	0.25
PM4	(0.03,0.04,0.06,0.07)	0.035	0.065	(0.5,0.6,0.7,0.8)	0.55	0.75
PM5	(0.66,0.72,0.83,0.89)	0.69	0.86	(0.5,0.6,0.7,0.8)	0.55	0.75
PM6	(0.14,0.16,0.19,0.21)	0.15	0.2	(0.3,0.4,0.5,0.6)	0.35	0.55
PM7	(0.04,0.05,0.06,0.07)	0.045	0.065	(0.3,0.4,0.5,0.6)	0.35	0.55
PM8	(0.84,0.87,0.92,0.95)	0.855	0.935	(0.5,0.6,0.7,0.8)	0.55	0.75
PM9	(0.09,0.09,0.10,0.11)	0.09	0.105	(0.7,0.8,0.9,1.0)	0.75	0.95
PM10	(0.73,0.76,0.84,0.89)	0.745	0.865	(0.3,0.4,0.5,0.6)	0.35	0.55
PM11	(0.10,0.11,0.12,0.13)	0.105	0.125	(0.1,0.2,0.3,0.4)	0.15	0.35
PM12	(0.73,0.76,0.84,0.89)	0.745	0.865	(0.3,0.4,0.5,0.6)	0.35	0.55
PM13	(0.10,0.11,0.12,0.13)	0.105	0.125	(0.5,0.6,0.7,0.8)	0.55	0.75
PM14	(0.09,0.09,0.10,0.11)	0.09	0.105	(0.3,0.4,0.5,0.6)	0.35	0.55
PM15	(0.84,0.87,0.92,0.95)	0.855	0.935	(0.5,0.6,0.7,0.8)	0.55	0.75
PM16	(0.66,0.72,0.83,0.87)	0.69	0.85	(0,0.1,0.2,0.3)	0.05	0.25
PM17	(0.11,0.12,0.15,0.17)	0.115	0.16	(0.5,0.6,0.7,0.8)	0.55	0.75
PM18	(0.05,0.06,0.08,0.09)	0.055	0.085	(0.1,0.2,0.3,0.4)	0.15	0.35

Table 8- Overall FWA scores of the agricultural services

Service type	ℓ_0	ρ_0	$\bar{X}$
PP1	0.111858	0.311858	0.211858
PR1	0.496032	0.696032	0.596032
PR2	0.567561	0.767561	0.667561
PR3	0.321264	0.521264	0.421264
PO1	0.371649	0.571649	0.471649
PO2	0.528125	0.728125	0.628125
PO3	0.112319	0.312319	0.212319

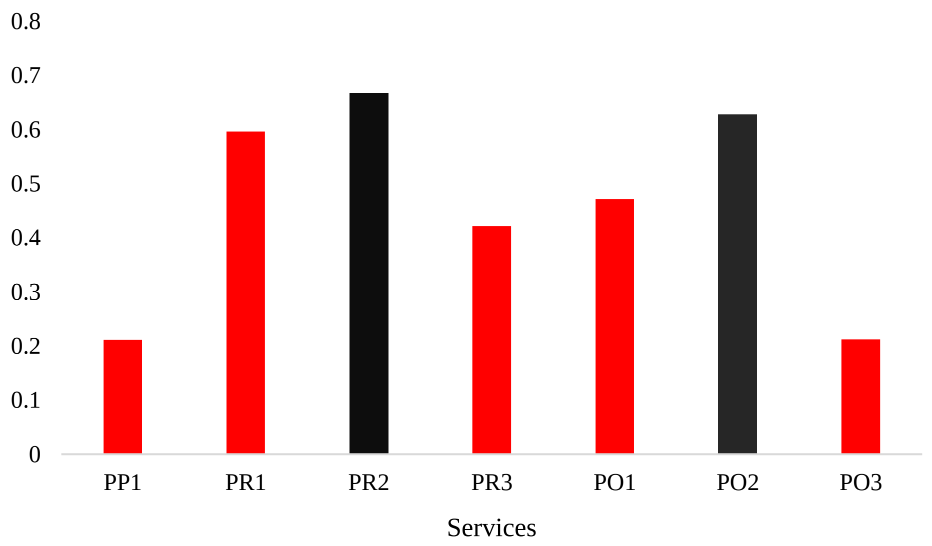

Fig.4. The values of $\bar{X}$ for agricultural services at $\alpha = 0.5$

According to the algorithm developed by Chang *et al.* (2009), the calculation of the benchmark should continue to improve the values of ℓ and ρ until the stop condition is satisfied. Since in this research, the number of evaluation criteria for each service type is small, no sensible improvement has been seen after calculating the ℓ_1 and ρ_1. So we reported the values computed in the first round of calculation in Table 9.

Using the αcut based method, from Fig.4, it can be concluded that red color services have smaller values $\forall \alpha \in (0.5, 1]$. Services with lower values are identified as the poorest quality services. Based on the study, it can be concluded that the services PO3, PP1, PR3, PO1, and PR1 are the worst performing services, in that order. Sustainable development requires sustainable enablers throughout the entire region. In the current supply chain, various services are assumed to be enablers for sustainable development. To implement any supply chain strategy, it is crucial to establish procedures for it (Mangla *et al.*, 2018). The procedure recommended in current research is to replace underperforming service providers with new ones.

Results of the second approach

To calculate A_i for each service, two parameters must be estimated, i.e. w_{ij} and X_{ij}. The first parameter is estimated using pairwise comparisons, but the second must be estimated in each case study. The value of X_{ij} is the value of PM membership function. Initially, it is essential to calculate the fuzzy number parameters and membership function. After that, based on the PM which was measured in the studied region, the value of X_{ij} can be calculated. The best type of fuzzy number in this study is trapezoidal, because of our aim to select the worst services using several PMs. For each PM, a unique trapezoidal fuzzy number is defined. The variable $\mu_{\tilde{A}}(x)$ is the membership function of each PM to the undesirable set, i.e. the value of 1 is completely undesirable while the value of zero is completely desirable performance. The direction of desirability differs for each project manager. The desirability of certain PMs has a positive correlation with their value (refer to Fig. 9), while for others, right and left trapezoidal fuzzy numbers are used to represent their desirability. The PM value in the studied region was estimated through a questionnaire administered to experts in the area. With the obtained values for PMs, the computation details of each PM membership function can be calculated as follows:

$$X_{11}(PM1) = \begin{Bmatrix} 0, & x < 30 \\ \frac{x-30}{80-30}, & 30 \le x \le 80 \\ 1, & 80 < x < 100 \\ 0, & 100 < x \end{Bmatrix} \qquad X_{11}(50) = \frac{50-30}{80-30} = (0.4) \qquad X_{12}(PM2) = \begin{Bmatrix} 0, & x < 0 \\ \frac{x}{20}, & 0 \le x \le 20 \\ 1, & 20 < x < 100 \\ 0, & 100 < x \end{Bmatrix}$$

$$X_{12}(10) = \frac{10}{20} = (0,0.5,1,0) \qquad X_{23}(PM7) = X_{23}(5) = \frac{5}{20} = (0,0.25,1,0) \qquad X_{13}(PM3) = \begin{Bmatrix} 0, & x < 0 \\ 1, & 0 \le x \le 80 \\ \frac{100-x}{100-80}, & 80 < x < 100 \\ 0, & 100 < x \end{Bmatrix}$$

$$X_{13}(0) = 1 \qquad X_{14}(PM4) = \begin{Bmatrix} 0, & x < 0 \\ 1, & 0 \le x \le 50 \\ \frac{100-x}{100-50}, & 50 < x < 100 \\ 0, & 100 < x \end{Bmatrix} \qquad X_{14}(70) = \frac{100-70}{100-50} = 0.6$$

$$X_{31}(PM8) = X_{31}(100) = 0$$

$$X_{32}(PM9) = X_{32}(100) = 0 \qquad X_{52}(PM13) = X_{52}(45) = 1 \qquad X_{21}(PM5) = \begin{Bmatrix} 0, & x < 0 \\ 1, & 0 < x \le 70 \\ \frac{100-x}{100-70}, & 70 < x < 100 \\ 0, & 100 < x \end{Bmatrix}$$

$$X_{21}(75) = \frac{100-75}{100-70} = 0.84 \qquad X_{22}(PM6) = \begin{Bmatrix} 0, & x < 0 \\ \frac{x}{70}, & 0 < x \le 70 \\ 1, & 70 < x < 100 \\ 0, & 100 < x \end{Bmatrix} \qquad X_{22}(50) = \frac{50}{70} = 0.71$$

$$X_{41}(PM10) = X_{41}(60) = \frac{60}{70} = 0.86 \qquad X_{42}(PM11) = \begin{Bmatrix} 0, & x < 0 \\ 1, & 0 < x \le 60 \\ \frac{100-x}{100-60}, & 60 < x < 100 \\ 0, & 100 < x \end{Bmatrix}$$

$$X_{42}(70) = \frac{100-70}{100-60} = 0.75$$

$X_{51}(PM12) = X_{51}(50) = 1$ $\quad X_{61}(PM14) = \begin{Bmatrix} 0, & x < 0 \\ \frac{x}{80}, & 0 < x \leq 80 \\ 1, & 80 < x < 100 \\ 0, & 100 < x \end{Bmatrix}$ $\quad X_{61}(80) = \frac{80}{80} = 1$

$X_{72}(PM17) = X_{72}(15) = \frac{15}{80} = 0.19$ $\quad X_{73}(PM18) = X_{73}(15) = \frac{15}{80} = 0.19$ $\quad X_{62}(PM15) = \begin{Bmatrix} 0, & x < 0 \\ 1, & 0 < x \leq 90 \\ \frac{100-x}{100-90}, & 90 < x < 100 \\ 0, & 100 < x \end{Bmatrix}$

$X_{62}(95) = \frac{100-95}{100-90} = 0.5$ $\quad X_{71}(PM16) = \begin{Bmatrix} 0, & x < 0 \\ \frac{x}{60}, & 0 < x \leq 60 \\ 1, & 60 < x < 100 \\ 0, & 100 < x \end{Bmatrix}$ $\quad X_{71}(70) = 1$

After this, the value of A_i can be calculated. For example, the value of A_1 is calculated as follows:

$$A_1 = \sum_{j=1}^{4} w_{1j} X_{1j} = (0.56 * 0.4) + (0.08 * 0.5) + (0.32 * 1) + (0.04 * 0.6) = 0.61$$

Similar to A_1, values for all A_i are calculated. The details of the computation for the service selection procedure have been summarized in Table 8. A unique fuzzy number is defined for each PM. The scale of each fuzzy number is specified by three values: a, b, and c. The values of the fuzzy number elements are selected based on the characteristics of each performance measure. For example, let PM1 have a value of 30 for variable a, 80 for variable b, and 100 for variable c. For this PM, the value of 100 represents the maximum time period available for the supplier to deliver inputs to the farmers. The value of a=30 indicates that there is no undesirability in delivering inputs during the first 30% of the designated period. Over time, the level of undesirability will continue to increase. After 80% of the time period has elapsed, the inputs become useless for the farmer. Similar to PM1, we assume fuzzy scales for other performance measures (PMs) ranging from 0 to 100. This simplifies computation and facilitates comparisons. The values of the fuzzy number may change in different conditions and case studies, requiring the definition of new values.

The related fuzzy number of PMs has been shown in Fig. 5. There are both left and right trapezoidal fuzzy numbers and their thresholds are different.

In the final step, after calculating the parameters of the model, the selected services that need to be imported to the service center are determined. A threshold is necessary for the procedure of selecting a service. The procedure involves a fuzzy decision-making process as one needs to consider the vague relationships in service selection. The proposed threshold can be determined based on the input of ASC's strategic managers, and it may vary across different regions. In this case study, a threshold of 0.6 has been selected. Services with a score above 0.6 will be selected and imported to service centers for more efficient distribution. The membership function in a fuzzy number represents the degree of membership of a service to the undesirable service set. This step will select the services that have a membership value of 1. According to the values of A_i, which are illustrated in Fig.6, the services PP1, PR1, PR3, PO1, and PO3 are selected.

Table 9- The values of the service selection procedure

Type of Service	**Performance measures**	**Fuzzy number**	**Trapezoidal fuzzy scale**				**The value of PM**	**Membership function (X_{ij})**	w_{ij}	A_i
			a	b	c	d				
(PP1)	PM1	LT*	0.3	0.8	1	1	50	0.40	0.56	0.61
	PM2	LT	0.2	0.5	1	1	10	0.50	0.08	
	PM3	RT**	0	0	0.8	1	0	1.00	0.32	
	PM4	RT	0	0	0.5	1	70	0.60	0.04	
(PR1)	PM5	RT	0	0	0.7	1	75	0.84	0.79	0.78
	PM6	LT	0.35	0.7	1	1	50	0.71	0.14	
	PM7	LT	0.2	0.5	1	1	5	0.25	0.07	
(PR2)	PM8	RT	0	0	0.5	1	100	0	0.83	0
	PM9	RT	0	0	0.5	1	100	0	0.17	
(PR3)	PM10	LT	0.3	0.7	1	1	60	0.86	0.75	0.83
	PM11	RT	0	0	0.6	1	70	0.75	0.25	
(PO1)	PM12	RT	0	0	0.6	1	50	1.00	0.75	1.00
	PM13	RT	0	0	0.5	1	45	1.00	0.25	
(PO2)	PM14	LT	0.3	0.8	1	1	80	1.00	0.13	0.57
	PM15	RT	0	0	0.9	1	95	0.5	0.87	
(PO3)	PM16	LT	0.2	0.6	1	1	70	1.00	0.63	0.70
	PM17	LT	0.5	0.8	1	1	15	0.19	0.26	
	PM18	LT	0.2	0.8	1	1	15	0.19	0.11	

*Left Trapezoidal (LT) **Right Trapezoidal (RT)

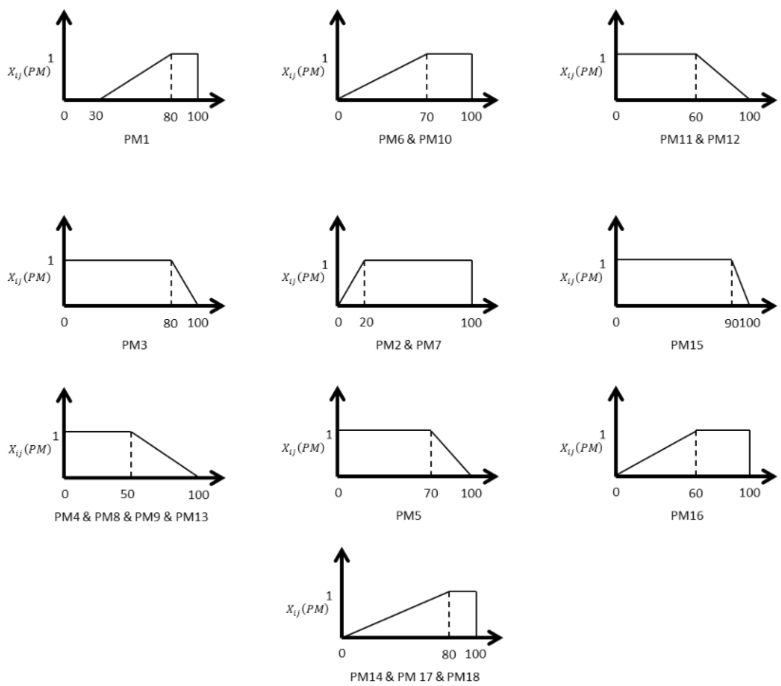

Fig.5. The schematic figure of PMs fuzzy number

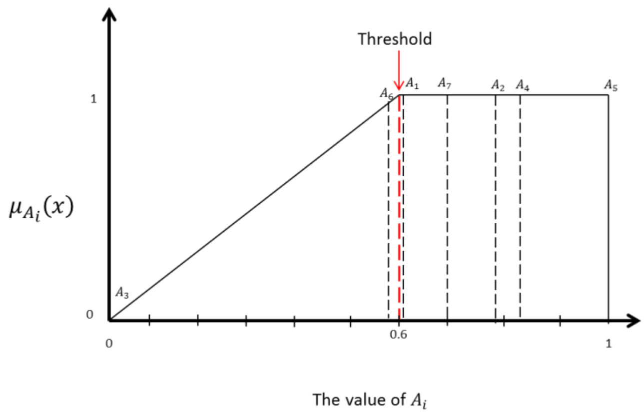

Fig.6. The fuzzy number of A_i

Conclusion

In this research, a new framework has been developed to investigate the performance measurement of agricultural services. The study focuses on seven types of agricultural services and conducts surveys on performance measures for each service type. Two fuzzy-based approaches are proposed to identify services in need of improvement. Improvement actions are suggested to address low performance in professional agricultural service centers, including resource allocation and replacing substandard service providers. Managerial implications include identifying service types and performance measures, utilizing fuzzy-based approaches for service selection, and implementing improvement actions and resource distribution. The research findings and framework can guide decision-makers in the agricultural sector to prioritize actions and allocate resources effectively. Implementing a feedback system is important for improving the results of service package implementation in service centers. Further research is needed to investigate budget and time allocation for improving low-performing services and the location of agricultural service centers.

Declaration of competing interests

The author declares that he has no conflict of interest.

Authors Contribution

M. Zangeneh: Conceptualization, Methodology, Data acquisition, Data pre and post processing, Statistical analysis, Writing and Editing

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مرتضی زنگنه [1*]

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چکیده

هدف اصلی این تحقیق ایجاد چارچوبی جامع برای ارزیابی عملکرد در زنجیره تامین کشاورزی و توسعه دو رویکرد برای بهبود آن می‌باشد. مرتبط‌ترین معیارهای عملکرد برای ارزیابی وضعیت فعلی خدمات در زنجیره تامین کشاورزی (ASC) انتخاب شدند. نوآوری این تحقیق به انتخاب شاخص‌های کلیدی عملکرد (KPI) و رویکردهایی برای افزایش عملکرد ASC مربوط می‌شود. چارچوب پیشنهادی شامل اندازه‌گیری عملکرد و فرآیند انتخاب خدمات است. دو رویکرد بر اساس KPIهای منتخب از خدمات در ASC توسعه داده شده است تا مشخص شود کدام خدمات نیاز به بهبود دارند. رویکردهای پیشنهادی ابزارهای قوی و همه‌کاره‌ای برای مدیران کشاورزی هستند تا زنجیره‌های تامین خود را ارتقا دهند. یک مطالعه موردی نیز از ایران ارائه شده است. چارچوب پیشنهادی برای این منطقه، رویکردهای انتخاب خدمات کشاورزی مانند مشاوره پس از تولید، حمایت مالی، مکانیزاسیون، مشاوره تجاری و تامین نهاده را در اولویت قرار می‌دهند. این چارچوب نشان می‌دهد که این خدمات باید به‌منظور پاسخ‌گویی بهتر به نیازهای منطقه مورد مطالعه بهبود یابد.

واژه‌های کلیدی: خدمات، زنجیره تامین، سنجش عملکرد، فازی، کشاورزی

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