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A PERFORMANCE EVALUATION SYSTEM FOR AGRICULTURAL SERVICES IN AGRICULTURAL SUPPLY CHAIN

Morteza Zangeneh[1], Peter Nielsen[2], Asadolah Akram[1], Alireza Keyhani[1]

[1] *University of Tehran, School of Agriculture & Natural Resources, Faculty of Agricultural Engineering and Technology, Department of Agricultural Machinery Engineering, Karaj, Iran*
[2] *University of Aalborg, Department of Mechanical and Manufacturing Engineering, Denmark*

Corresponding author:
Morteza Zangeneh
University of Tehran, School of Agriculture & Natural Resources
Faculty of Agricultural Engineering and Technology
Department of Agricultural Machinery Engineering,
Karaj, Daneshkade Street, Iran
phone: (+98) 918-911-0115
e-mail: mzangeneh@ut.ac.ir

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Abstract
The aim of this paper is comparing all possible scenarios to improve the performance of agricultural supply chain (ASC). For this purpose, at first all scenarios is discussed and the main constraints, i.e. available budget and time, is considered. In this study the drivers to improve the performance of ASC is select and distribute the best agricultural service packages in the target ASC. All discussed scenarios need a selection procedure. So a multi-level approach is developed to select the best service package for each scenario. All selection methods are based on performance measurement which had been selected in first level of the approach. Fuzzy decision making and Analytic Hierarchy Process have been used for the approach. A numerical example is solved at the end of the paper to show the capability of the approach and comparing the scenarios.

Keywords
pservice, performance measurement, supply chain, selection, agriculture.

Introduction

An agri-food chain is nothing more than a supply chain which produces and distributes an agricultural or horticultural product and where product flows and information flows take place simultaneously [1]. What makes agri-food supply chains different from other supply chains is (1) the nature of production, which is partly based on biological processes, thus increasing variability and risk; (2) the nature of the product, which has specific characteristics like perishability and bulkiness that require a certain type of supply chain; and (3) the societal and consumer attitudes towards issues like food safety, animal welfare and environmental pressure [2].

Farmers around the world face many constraints, including access to financing, inputs, and technologies that prevent them from upgrading production [3]. The limited shelf lives of food products, requirements with regard to temperature and humidity, possible interaction effects between products, time window for delivering the products, high customer expectations, and low profit margins make food distribution management a challenging area that has only recently began to receive more attention in the operations management literature [4].

Supply chain of agricultural and food products face to several challenges due to inherent characteristics of agricultural products and also regard to their effects of human health. These challenges can be managed in different level of management practices, i.e. strategic, tactical and operational. In this study the challenges are related to services in agricultural supply chain, which be almost placed on strategic level of management, is considered. Many of these challenges can be managed by providing services or adapting the provided services for the supply chain.

The success of ASC and sustainability of it depends on monitoring its performance. ASC faces to many participants in its chain, so the performance of ASC can influence its success completely. In following section, the literatures on performance measurement of ASC investigated.

Planning the actions to improve the performance maximally is a combinatorial optimization problem that can be found near optimal solution with acceptable computational time by using approximated approach. Genetic algorithm, neural network approach and ant colony algorithm are well-known approximated approaches to solving combinatorial optimization problems [5]. Planning the improvement actions is a complex decision-making process. Yang [6] developed a comprehensive model to plan improvement actions for enhancing the supplier's performance. However, performance improvement is an integral aspect of management that requires a systemic approach to help managers.

Decision making to choose an alternative which could enhance the performance measures and therefore improve the main targets of ASC is very difficult, due to the relationships and inherent complexity in service supply chains, so we need an effective procedure to select the best alternatives (agricultural services).

In this study the drivers to improve the performance of ASC is selecting and distributing best agricultural service packages in target region. Selecting and implementing best service packages depend on the time and budget availability for strategic managers. So in this research different decision time periods considered to introduce best service package selection procedure to perform best selection.

Material and methods

In this research a flexible and multi-purpose approach Is developed. This approach has four levels and covers four scenarios for selecting best service packages. According to the available time and budget for improving the agricultural supply chain performance, each of these scenarios can be selected. In Fig. 1 a summary of whole approach has been shown. Level 1 and 2 is common for all scenarios. At first le-

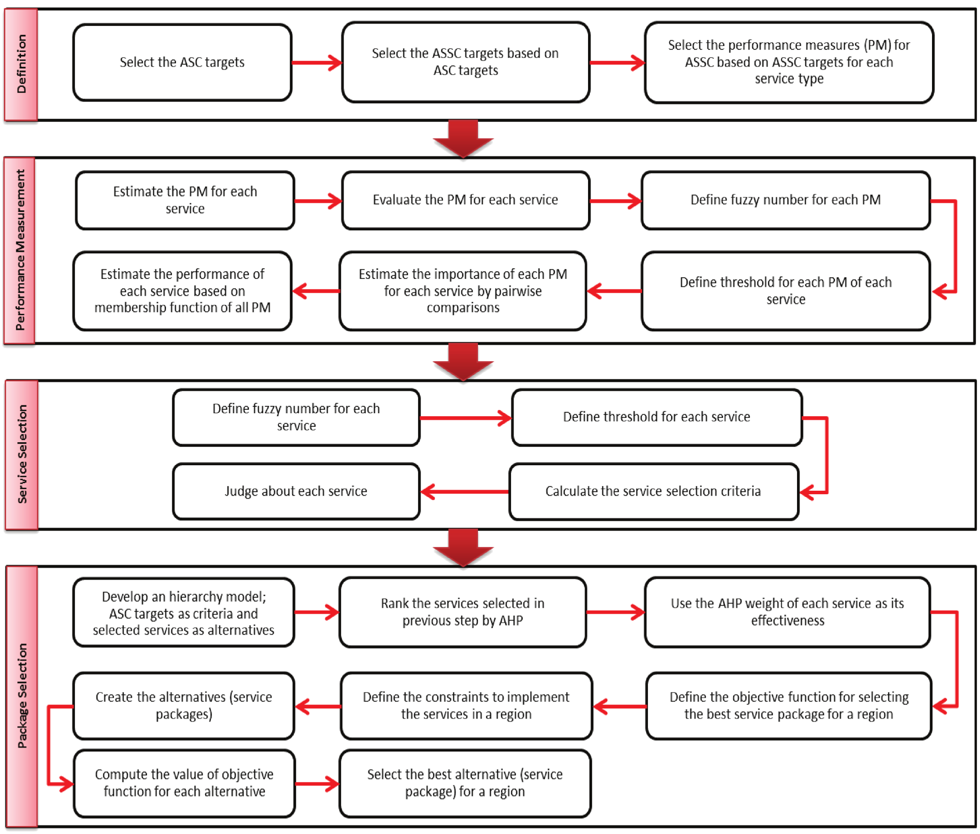

Fig. 1. The comprehensive summary of approach for improving ASC performance.

vel, general definitions about goals of agricultural supply chain and also agricultural service supply chain will be made. Furthermore, performance measures for evaluating the current situation of agricultural supply chain will be selected. At level two, some measurements and evaluations will be performed on selected performance measurements. Third level refers to selecting services which has not acceptable performance based on studied performance measurements. Last level will be used to perform required analysis to run scenarios 1 and 2.

In this study four main levels developed to produce improvement drivers for ASC. One of the main factors of strategic decision making, i.e. time, has been considered to distinguish between all possible scenarios to replace the service supplier in an agricultural supply chain management. Another important factor is available budget which may limit solutions for performance improvement problem. The schematic figure of possible results of implementing mentioned scenarios has been shown in Fig. 2. As can be seen in this figure when the available budget and time is too restricted, managers must select alternatives which results most effectiveness on the performance and solve performance problems in the supply chain. By increasing the available time and budget other scenarios can be implemented. The goals and priorities of managers

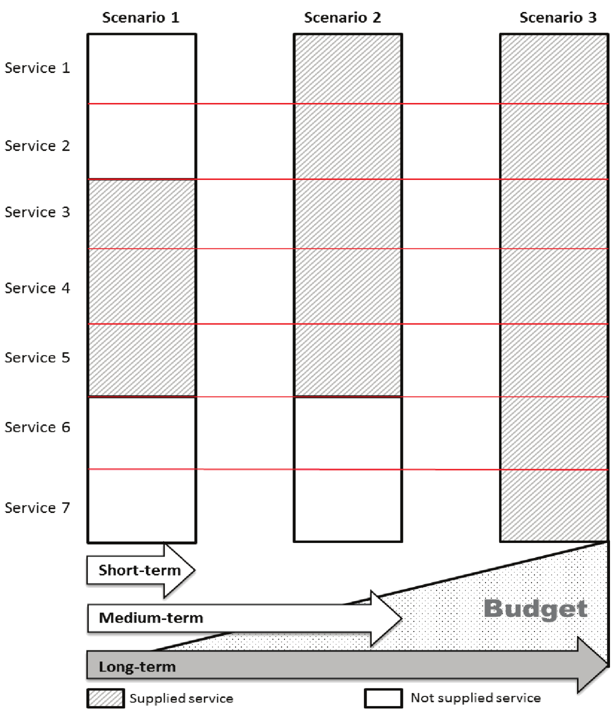

Fig. 2. Different scenarios for service selection.

will lead to select scenario 2 or 3. The scenario 2 can improve the performance of supply chain by substitution inefficient service suppliers with efficient suppliers, while third scenario can be selected when the managers are seeking other service suppliers to maximize effectiveness of new scenario by spending available budget and time. This paper propose that substitution of current service suppliers by professional service centers which can supply high quality services for farms/orchards is best driver to improve the performance of whole agricultural supply chain. Since these service centers can provide required services for all supply chain elements, all demands will go to them in long term period. But this evolution in a target region needs huge budget and too much time.

In following section the steps of each level has been described in details:

Level 1

Step 1

Manzini and Accorsi [7] emphasized on quality, safety, sustainability and efficiency as the main key performance indicators of the food chain. Joshi, Banwet [8] proposed following targets in an ASC: cost, quality and safety, traceability, service level, return on assets, innovativeness and relationship. As can be seen in the literatures, different targets can be selected in each agricultural region and commodities, but in current research the following targets have been considered for ASC:

- Minimize the production cost per unit of product;
- Maximize the product quality, includes health and safety;
- Maximize the total production of the ASC;
- Maximize the production efficiency.

Step 2

The goals of services in ASC (or Agriculture Service Supply Chain (ASSC) targets) should be defined based on the targets of ASC. So in this study following goals considered for ASSC which influences the ASC targets:

- Optimize the service delivery performance; including service order lead time and customer query time;
- Minimize the service cost; including cost paid by customers to receive the services;
- Maximize the service quality; view point of technical, health and environmental aspects;
- Maximize the service flexibility; including innovation, reflect to customer needs and etc.

Table 1
Framework of performance measures of services in ASC.

Production Level	Type of Service	Performance measures	References
Pre-production (PP)	1. Input supply (PP1)	Supplier's delivery performance (on time delivery, delivery reliability performance)	[9]
		Supplier's pricing against market	[9]
		Quality of supplier's inputs	[10]
		Supplier's auxiliary services (booking, cash flow method, purchase order cycle time, back order)	[9]
Production (PR)	1. Mechanization services (PR1)	Quality of services	[10]
		Customer query time	.[11]
		Service pricing against market	[9]
	2. Consulting services (PR2)	Customer satisfaction	[2]
		Flexibility of services to meet customer needs	[9]
	3. Financial services (PR3)	Customer query time	[11]
		Flexibility of services to meet customer needs	[9]
Post production (PO)	1. Consulting services (PO1)	Customer satisfaction	[2]
		Flexibility of service systems to meet customer needs	[9]
	2. Inspection services (PO2)	Customer query time	[11]
		Reliability of performance	.[12]
	3. Business services (PO3)	Purchase order cycle time	[12]
		Shipping errors	[2]
		Service pricing against market	[9]

Step 3

In this section, a framework for performance measures and metrics is presented for investigating current situation of services implemented in agricultural supply chain of farm based commodities includes farming and horticulture (see Table 1). According to the three major level of agricultural supply chain (including: pre-production, production and post-production) and their related services, suitable metrics selected.

Level 2

Step 1

Some services have several PMs and evaluating each service will perform according to their PMs. Since the relative importance of PMs is not similar, an importance factor w_{js} defined to consider their importance in evaluations. The value of w_{js} for performance measurement s of service j will be estimated using pairwise comparison survey between the performance measurements of service i

$$\sum_{s=1}^{v} w_{js} = 1 \forall j \qquad 0 < w_{js} \leq 1.$$

Step 2

The value of PMs for each service should be estimated using some data collecting methods, such as reviewing the local databases, questionnaire and interview with farmers, local managers and etc. in studied ASC/region. It is better that all PMs be estimated in one scale, e.g. percent. The value of s-th PM of j-th service called Z_{js}.

Step 3

The desirability of each performance measurement for service considered as a unique left trapezoidal (or right trapezoidal) fuzzy number. The left trapezoidal numbers are used for the performance measurement which the bigger value of performance measurement is not preferred and the right trapezoidal is used for performance measurements which the lower value is not preferred (see Fig. 3 and 4). In other words, higher value of membership function for PM is equal to higher undesirability of that PM. For example the value of 1 for membership function of one PM, means that the PM is not desirable extremely.

The membership function of performance measurement to the undesirability is as follows:

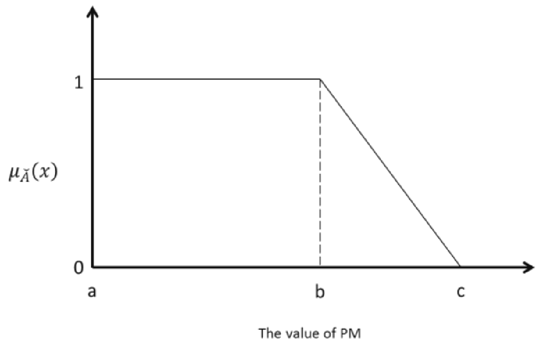

Fig. 3. The right trapezoidal fuzzy number for PM evaluation.

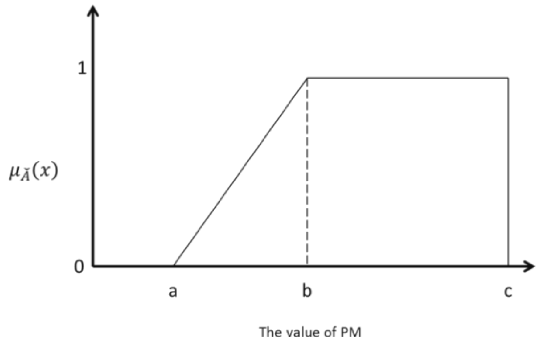

Fig. 4. The left trapezoidal fuzzy number for PM evaluation.

For left trapezoidal fuzzy numbers

$$Z_{js} = \mu_{\tilde{A}}(x) = \left\{ \begin{array}{cc} 0, & x < a \\ \dfrac{x-a}{b-a}, & a < x \leq b \\ 1, & b < x < c \\ 0, & c < x \end{array} \right\}.$$

For right trapezoidal fuzzy numbers

$$Z_{js} = \mu_{\tilde{A}}(x) = \left\{ \begin{array}{cc} 0, & x < a \\ 1, & z < x \leq b \\ \dfrac{c-x}{c-b}, & b < x < c \\ 0, & c < x \end{array} \right\}.$$

Step 4

Threshold of each performance measure can be specified by experts and strategic level managers. If the value of a performance measure of a service be less/more than threshold (according to its characteristics which should be maximized or minimized), then that service should be implemented in that supply chain by another service supplier.

Step 5

After specifying the threshold for each PM, the membership function value of PMs can be estimated using related trapezoidal fuzzy formula which specified in step 3.

Level 3

Step 1

Similar to step 3 in level 2, the desirability of each service consider as a unique left trapezoidal fuzzy number (see Fig. 5). The left trapezoidal numbers are preferred for the services which the bigger value of their selection variable is not preferred

$$\mu_{A_j}(x) = \left\{ \begin{array}{cc} 0, & x < a \\ \dfrac{x-a}{b-a}, & a < x \leq b \\ 1, & b < x < c \\ 0, & c < x \end{array} \right\}.$$

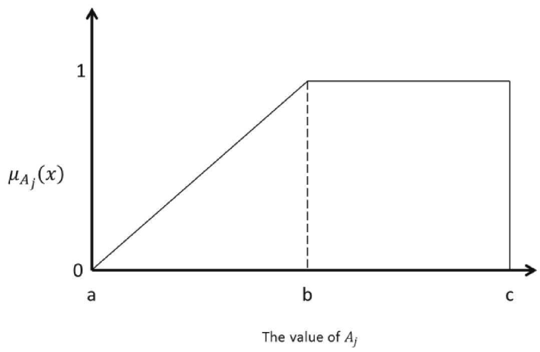

Fig. 5. Left trapezoidal Fuzzy number for the A_j.

Step 2

If the membership function of service j be worse than threshold b for left, then the service j can be considered as an alternative for the problem of performance improvement. The value of membership function, Z_{js}, and the relative importance of all PM of each service type used to select the worst services viewpoint of their performance. These services will be selected to distribute by service centers and improve the service in the studied region.

Step 3

The formulation of proposed service selection procedure is as follows:

$$A_j = \sum_{s=1}^{V} w_{js} Z_{js} \quad \forall j.$$

Parameters: w_{js}, Z_{js}

$$\sum_{s=1}^{v} w_{js} = 1 \quad \forall j$$

$$0 < w_{js} \leq 1.$$

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

Z_{js}: The membership function value of performance measurement s of service j.

Indices: j, s

j – the index of services $j = 1, 2, ..., m$; s – the index of performance measurement $s = 1, 2, ..., v$

$$0 \leq w_{js} Z_{js} \leq 1.$$

Step 4

Using the proposed procedure, the service j will be selected to import in service center if the value of $A_j = w_{js} Z_{js}$ be more than b (b is a threshold for service j) because the current performance of them is not acceptable, otherwise will not selected. The threshold which is required for service selection procedure can be selected according to the opinion of strategic managers of ASC, and it is completely different in various regions. The left trapezoidal fuzzy number selected here to select worst services, because A_j was calculated using Z_{js} and bigger value of Z_{js} indicates more membership degree to undesirable service set. So whatever A_j is bigger, the chance of service j being selected will increase.

Level 4

Scenario 1

Step 1

Investigation the relationship of alternatives, targets with themselves and with others (i.e. internal and external relationships and links of the evaluation system elements) is a main step to select most effective service package. The results of this step will be used for effectiveness variable of each alternative on upper level of performance evaluation system. Several methods can be used in this case such as: Analytical Hierarchy Process (AHP), Evolutionary Factor Analysis (EFA), Graph Theory (GT), Decision – Making Trial and Evaluation Laboratory (DEMATEL) (Grover, Agrawal [13], Uysal [14]). But here we used AHP method because of its simplicity of calculation and relevance in similar studies. The AHP model of this research has been shown in Fig. 6.

The interaction of ASC goals and agricultural services has critical role in usefulness of implementing each service to improve the performance of ASC. After developing the AHP model, weights of alternatives (services) will be calculated in this step. The final weights of AHP model for each service used for ranking the services viewpoint of their role on performance improvement.

The calculated weight of each service in step 2 has been used as their effectiveness factor in objective function to select best service package in scenario 1.

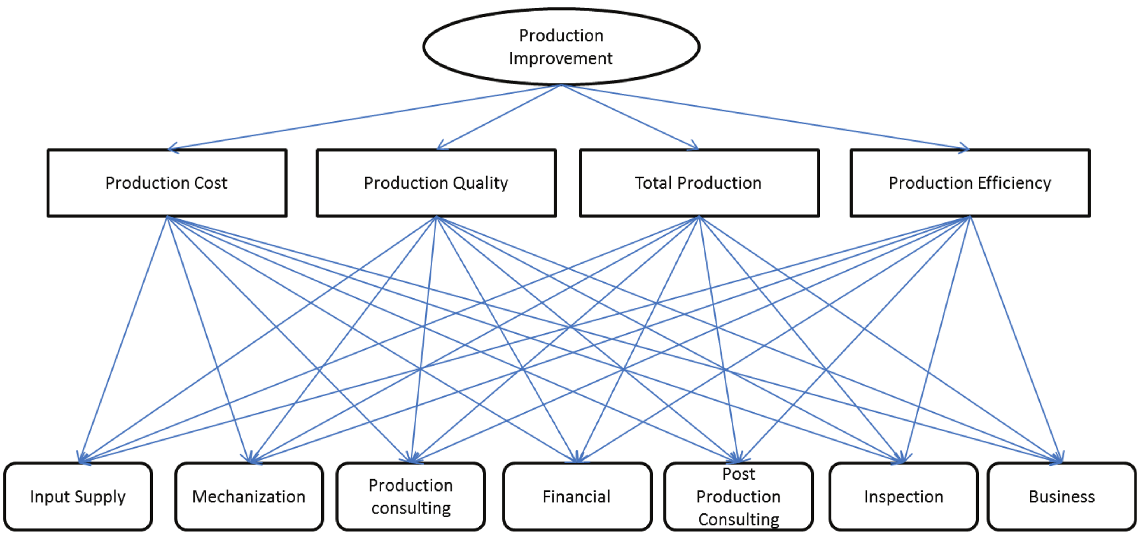

Fig. 6. The AHP model for estimating service effectiveness.

Step 2

After calculating the effectiveness of each service type on ASC performance, using following integer linear model we are going to select the most effective service package. The objective function of this step is maximization of service effectiveness. In this regard, available budget and time for setup service packages in each region are main constraints. Third constraint ensures that one service center created in each region.

$$\text{Max} \sum_{i=1}^{n} \sum_{k=1}^{p} Y_i^k * E_i^k.$$

Subject to:

$$\sum_{i=1}^{n} \sum_{k=1}^{p} X_j^k * Y_i^k \le \varphi,$$

$$\sum_{i=1}^{n} T_i^k * Y_i^k \le \gamma_k,$$

$$\sum_{k=1}^{p} Y_i^k = 1,$$

where
Decision variable is: Y_i^k

$$Yi^k = \left\{ \begin{matrix} 1 & \text{if service package } i \text{ is implemented in region } k \\ 0 & \text{otherwise} \end{matrix} \right\}$$

X_i^k – the setup cost of service package i in the region k.

The indices are: i – the index of service package, $i = 1, 2, ..., n$; j – the index of service, $j = 1, 2, ..., m$; k – the index of region, $k = 1, 2, ..., p$.

The parameters are:

T_i^k – the time needed for set up (completion) of service package i in region k; γ_k – the maximum time available for improving the performance of ASC in region k; φ – the maximum budget available for package implementation to improve the performance of ASC; E_i^k – the effectiveness of package i on performance of ASC in region k.

Step 3

Generally seven types of services specified in ASC. These services and their combinations form the alternatives for the ASSC improvement. Combination is a way of selecting members from a grouping, such that the order of selection does not matter. The combination of service packages in our study can be calculated using the combination formula:

$$C(n,k) = \binom{n}{k} = \frac{n!}{k!(n-k)!},$$

where n – the number of all services, k – the number of distinct elements.

In our case, the total number of service packages is:

$$\binom{7}{1} + \binom{7}{2} + \binom{7}{3} + \binom{7}{4} + \binom{7}{5} + \binom{7}{6} + \binom{7}{7} = 127.$$

In other words, we are introducing 127 packages of agricultural services to the ASC.

The main challenge in this case is that what package/alternative is suitable for ASC of each region. Since the structure and conditions of different regions/counties are not similar, so the suitable packages for each of them will be different.

Step 4

Using combination formula described in step 3, service packages as feasible solution space of our problem developed. The value of effectiveness, setup budget and time of each service package can be calculated using following equations:

$$E_i^k = \sum_{i=1}^{n} E_j^k \quad \forall k,$$

$$X_i^k = \sum_{i=1}^{n} X_j^k \quad \forall k,$$

$$T_i^k = \sum_{i=1}^{n} T - j^k \quad \forall k,$$

where E_j^k – the effectiveness of service j in service package i in region k; X_j^k – the setup cost of service j in service package i in region k; T_j^k – the setup time of service j in service package i in region k.

Step 5

At last step of this approach using IBM ILOG Optimization Studio the objective function has been solved and best service package has been selected. Any solver or optimization environment which can run medium size models can be used to solve this objective function.

Scenario 2

In this scenario more budget and time is available for decision makers to select services which need to be supplied in the region. So in this scenario an optimization problem arises similar to scenario 1, but the budget and time constraints are less that first scenario.

Scenario 3

In this scenario all agricultural services will be supplied by the service centers for the clients. This scenario need most time and budget and in real cases has least chance to be done. But in some cases if the service center supply high quality services for clients with least price, in long term it is predicted that this scenario can be applied.

A numerical example

A numerical example is solved in this section to show the computation details of proposed strategy and also its capability to improve the performance of ASC.

Level 1

The goals for ASC and ASSC as same as developed in this paper for this numerical study. Table 10 shows the values of performance measures.

Level 2

The importance of each PMs against other PMs (w_{js}) is calculated by pairwise comparisons. The results can be seen in Table 2 to Table 8. The importance weight in each region and each agricultural commodity can be different, so it is highly recommended that in any use of this methodology, unique w_{js} be computed.

Table 2
The pairwise comparison matrix of performance measures for service PP1.

PP1	PM1	PM2	PM3	PM4
PM1	1	4	1/7	3
PM2	1/4	1	1/6	2
PM3	7	6	1	9
PM4	1/3	1/2	1/9	1

Table 3
The pairwise comparison matrix of performance measures for service PR1.

PR1	PM5	PM6	PM7
PM5	1	8	5
PM6	1/8	1	1/3
PM7	1/5	3	1

Table 4
The pairwise comparison matrix of performance measures for service PR2.

PR2	PM8	PM9
PM8	1	5
PM9	1/5	1

Table 5
The pairwise comparison matrix of performance measures for service PR3.

PR3	PM10	PM11
PM10	1	7
PM11	1/7	1

Table 6
The pairwise comparison matrix of performance measures for service PO1.

PO1	PM12	PM13
PM12	1	5
PM13	1/5	1

Table 7
The pairwise comparison matrix of performance measures for service PO2.

PO2	PM14	PM15
PM14	1	1/7
PM15	7	1

Table 8
The pairwise comparison matrix of performance measures for service PO3.

PO3	PM16	PM17	PM18
PM16	1	5	5
PM17	1/5	1	1/3
PM18	1/5	3	1

The characteristics of performance measures such as their relative importance for each service type, fuzzy number type (Left or Right) and their threshold values has been illustrated in Table 9.

Level 3

The schematic figure of related performance measure fuzzy numbers has been shown in Fig. 7.

Table 9
The characteristics of performance measures.

Services	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
Weight	0.17	0.08	0.68	0.05	0.74	0.07	0.18	0.83	0.17	0.87	0.13	0.83	0.17	0.13	0.87	0.70	0.10	0.20
Fuzzy number	L	L	R	R	R	L	L	R	R	L	R	R	R	L	R	L	L	L
Threshold value	80	20	80	50	70	70	20	50	50	70	60	60	50	80	90	60	80	80

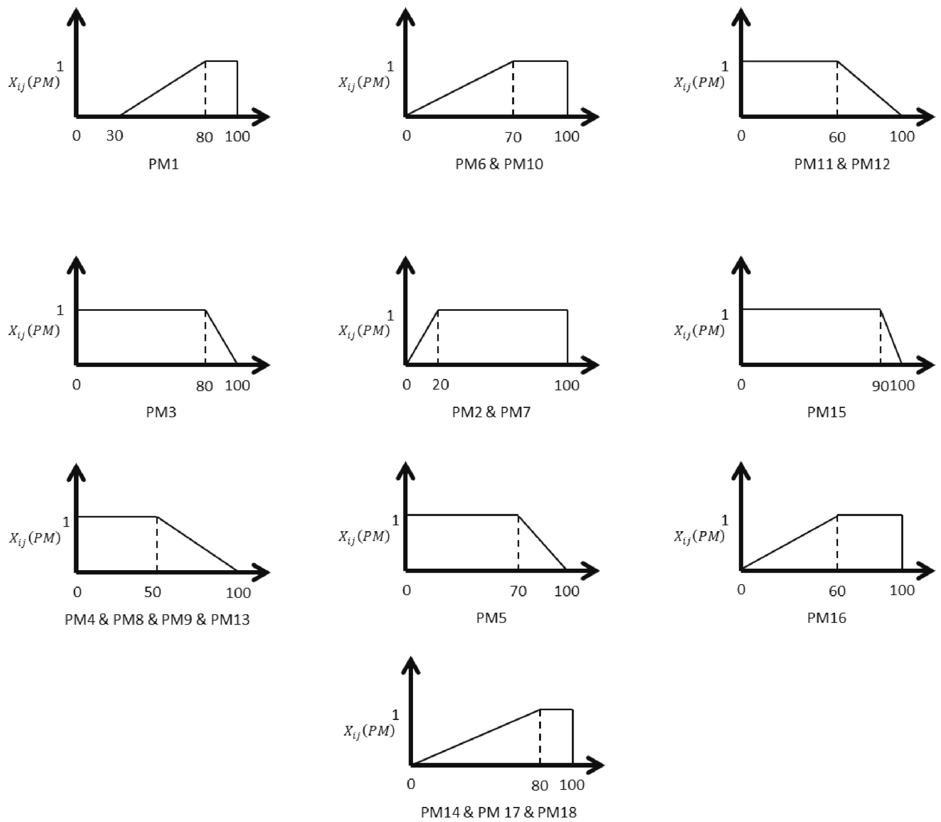

Fig. 7. The schematic figure of PMs fuzzy number.

Table 10
The values of service's performance measurement analysis.

Services	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
w_{js}	0.17	0.09	0.68	0.06	0.75	0.07	0.18	0.83	0.17	0.87	0.13	0.83	0.17	0.13	0.87	0.70	0.10	0.20
PM value	40	60	30	50	70	100	40	70	10	30	60	70	80	100	60	40	20	50
Z_{js}	0.2	1	1	1	1	1	1	0.6	1	0.43	1	0.75	0.4	1	1	0.67	0.25	0.63
A_j	0.864				1			0.668		0.5		0.69		1		0.62		

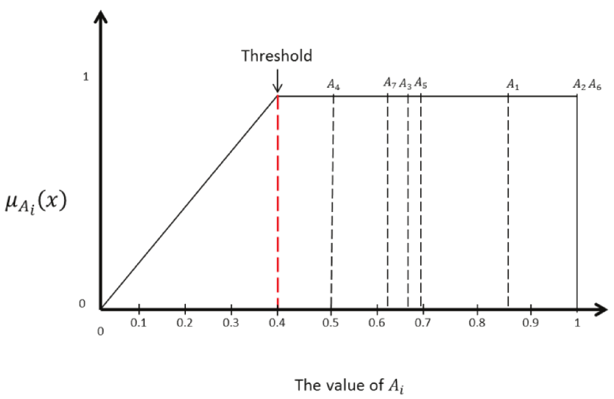

Fig. 8. The fuzzy number of A_i.

The computation detail of membership function value of first performance measure has been shown. The results of other PMs illustrated in Table 10.

$$Z_{11}(PM1) = \begin{pmatrix} 0, & x < 30 \\ \dfrac{x-30}{80-30}, & 30 \le x \le 80 \\ 1, & 80 < x < 100 \\ 0, & 100 < x \end{pmatrix},$$

$$Z_{11}(40) = \frac{40-30}{80-30} = (0.2),$$

$$A_1 = \sum_{s=1}^{V} w_{js} Z_{js} = (0.17 * 0.2) + (0.09 * 1) + (0.68 * 1) + (0.06 * 1) = 0.864.$$

Level 4

According to the AHP model which previously developed, synthesized weights for each service type calculated as their effectiveness parameter (Table 11).

Table 11
The overall synthesized weights for alternatives (service type) in AHP.

Production stage	Service type	Weight (E_1)
Pre-production	(PP1)	0.0973
Production	(PR1)	0.2205
	(PR2)	0.1976
	(PR3)	0.0554
Post-production	(PO1)	0.2251
	(PO2)	0.1696
	(PO3)	0.0341

A summary of characteristics of agricultural services reported in Table 12. Using these services, different combination of service packages constructed and using the optimization model, the best service package for each scenario is selected. The results of PM evaluation system developed in this paper can be seen in Table 13. The first scenario has least service numbers, while third scenario has the most. The difference between scenarios is related to available time and budget for them. The services PR1 and PO1 are common in all scenario results and can be understood that these services are more important than others for studied numerical example.

Table 12
Characteristics of agricultural services.

Service type	PP1	PR1	PR2	PR3	PO1	PO2	PO3	Sum
T_1^k (month)	3	6	2	4	1	2	4	22
X_1^k (million $)	0.73	10.05	0.09	0.09	0.09	0.09	0.57	11.71

Table 13
The results of different scenarios.

Scenario	Time constraint (month)	Budget constraint (million $)	Selected service package	Services in the package
1	12	5	P38	PP1,PR1, PO1
2	18	10	P68	PR1,PR2, PR3,PO1
3	24	15	P127	PP1,PR1, PR2,PR3, PO1,PO2, PO3

Conclusions

In this paper a performance evaluation system developed to select agricultural services which should be improved through an agricultural supply chain. This methodology at first selects services which their performance is not good enough using fuzzy decision making process. The results of this phase depend on data collected in the studied supply chain. Since the proposed service selection approach use current performance of services in the supply chain, so it can be a very good tool to decide about them. But sometimes imprecise data may lead to incorrect results because this methodology depends on local data. Then using these inefficient services, all possible combinations of services constructed and the problem is that what service package should be implemented in one agricultural supply chain. The available time and budget horizon dictate different scenarios. Short term to long term scenarios applied to select best decision about services. The main advantage of this methodology is considering both administrative and technical aspects to find and propose best service package. This methodology can be applied in any agricultural supply chain and all agricultural regions with minor modification. The results of developed approach are case-specific. In future studies of this field, more constraints which reflects real conditions of agricultural supply chain can be added to the service package selection phase to improve the applicability of the methodology.

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