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# SUPPLY CHAIN CONTRACT SELECTION IN THE HEALTHCARE INDUSTRY: A HYBRID MCDM METHOD IN UNCERTAINTY ENVIRONMENT

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***ABSTRACT***

The aim of this research study is to address a critique of how and when a supply chain contract is selected based on critical success factors (CSFs) utilizing stepwise weight assessment ratio analysis (SWARA) and Evaluation by an Area-based Method of ranking (EAMR). This research study ranked supply chain contracts by the EAMR in uncertainty environments, such as when breaking down the health care industry. This is done by providing a theoretical framework for sustainable entrepreneurship in telecommunications industry, focusing on managerial and operational practices that should be modified, in accordance to a set of CSFs identified from experts in fertility hospital. As a novel strategy, in this research, the initial factors of selecting customized Supply Chain Management (SCM) were extracted via a Delphi method along with the EAMR to symbolize a decision matrix that needs primary weights acquired through the SWARA method by hesitant fuzzy number. CSFs for achieving SCM contract selection in fertility hospitals were found to rely on a tripod based on effectiveness, transparency, and accountability that are embedded within the ambit of managerial and operational practices, such as focusing and reducing cost and based on these factors the best SCM contract must be selected. Besides, the EAMR method has more reliability than other similar MCDM methods such as TOPSIS, MOORA, VIKOR, and so on main contribution of this paper is the combination of SWARA, EAMR, and using hesitant fuzzy set in the EAMR

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method. Finally, the result indicates that hospitals based on these CSFs must be selected contracts.

**Keywords**: Critical Successful Factors (CSFs); Delphi method; Hesitant fuzzy sets; SCM contract; Supply Chain Management (SCM)

## 1. INTRODUCTION

The healthcare industry is the backbone of developing economies as it serves the entire nation and encompasses one of the crucial indicators that help translate progress. Lately the healthcare industry has been lagging behind according to various indicators such as lack of instruments, limited medicine (Dafny, 2019), unqualified doctors and physician, cheap medical treatments, inadequate logistics, institutional pressures, and deprived medical machinery.

In fact, for people suffering from chronic diseases and for their therapeutic conducts, there is no appropriateness of suitable economic eminences and frontrunners who guide them meritoriously. Local governments need to consider healthcare industry rebuilding strategy programs such as settlements of new and affordable hospitals, sufficient training and development programs to cultivate doctor and physician knowledge and assistances, value-added practices, and education for young nurses (Dafny, 2019; Federgruen et al., 2019).

The status of the health care supply chain also matters, such as manufacturer permits through the many echelons of the supply chain having an impact on the initial cost to meet consumer petitions (Pohjosenperä et al., 2019). Each supply chain member interacts with its upstream and downstream members (Ahmadi et al., 2019). The supply chain can be divided into a centralized and a decentralized structure (Fan et al., 2019).

In a centralized supply chain, adherents of the chain interact with one another, and the perseverance of this collaboration is to exploit profits for the all-inclusive supply chain in the long run. In a centralized structure, conclusions are made by a single entity, which is accountable for augmenting and synchronizing the supply chain, while in the decentralized supply chain each adherent improves its own profit without respect to synchronization and interaction with other members of the chain. The problem is that this will not elevate the all-inclusive supply chain (Eckerd et al., 2016; Modak et al., 2019).

In spite of all the disputes, a critical discussion in supply chain management is to avert sub-optimizations without regard to supply chain synchronization. A contract mechanism is an apparatus used to synchronize members, encouraging them to segment risks and rewards by

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amending or adapting trading situations by presenting trading parameters between the members of the chain (Fan et al., 2019).

Another anticipated feature of the win-win contract mechanism is that it upturns the profits of each of the contributing entities compared to the decentralized state. Supply chain coordination to support chain member strategies and maximize the probable advantage for the supply chain has been the emphasis of much research in the last decade. To achieve coordination, it is possible to use a variety of mechanisms with contracts being one of the most significant (Fan et al., 2019; Kees et al., 2019).

Supply Chain Management (SCM) is the system of the process that resolves to satisfy customers by managing distribution, raw material, factory, and other stakeholders all add value to the goods and services, conceptualizing the history of SCM back to 1982 by Keith Oliver (Ernst & Haar, 2019).

Unpacking the healthcare industry, particularly in hospitals, the requirement of supply chain famous for both pharmacies equipment, and other need-oriented programs. Similarly, in SCM contracts, suppliers guarantee that they provide all materials, goods, and information based on the time stated in the contract. Therefore, to close contracts is more imperative for suppliers in this subdivision Comment: This sentence does not make any sense at all. I can't even understand what the main idea is here to try to revise it. Please check and rewrite this sentence. (Meng et al., 2017).

Nonetheless, these contracts have some articles that are important for buyers. This comparison is complicated for hospitals. Providing such elements is intricate because some of the drugs and instruments come from foreign countries and if suppliers do not have any precise date, [they frontage to privation of constituents and cannot contentment of their obligations alternatively (Kees et al., 2019). If buyers keep to the strict contract in some crises, they may not have any materials because of the erroneous anticipation.

Certain apparatuses lead to an upsurge of shrinkages in the budget of hospitals and perhaps cause interruption to transporting equipment, and the consequence of that is the death of individuals. Numerous suppliers exist on this matter for providing material for hospitals, and because of that buyers need to hierarchically rank them for the best assumption of SCM contracts (Liu et al., 2015).

Numerous approaches and methods have been recently fashioned for selecting contracts based on critical factors (Wan et al., 2019). One of the significant methods, namely the MCDM

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(Multi-Criteria Decision Making) method, comprises pairwise comparison methods and decision matrix methods (Peres et al., 2019). Indecision matrix methods need primary weights. In a similar fashion, this research study is more interested in adopting an EAMR (Evaluation by an Area-based Method for Ranking) method, which is the decision matrix.

SWARA (Step-wise Weight Assessment Ratio Analysis) is the crucial approach to find and indicate the various weights of factors included and is used as a kind of decision matrix method using primary weights for reaching results to break down primary weights. Indeed, SCM contracts of fertility centers are selected based on customized CSFs, and are ranked by extended hybrid methods of MCDM methods. Since reaching a decision in this hot biosphere is identical and rigid, some approaches need to be established that help us make a decision. The hesitant fuzzy number is reaching a decision in an environment of uncertainty, thus allowing decision-makers to render a verdict.

This paper entails six parts. After the introduction section, the literature review of SCM contracts is illustrated in part two. Part three lists the MCDM methods and part four breaks down the research methodology. The data analysis is shown in section five, while the conclusion is given in part six.

## 2. LITERATURE REVIEW

### 2.1. Healthcare Industry

The healthcare industry in Iran has a quite suitable situation with a health care market of 96 billion dollars in 2017 (Emamgholipour & Agheli, 2019). Healthcare spending reached 50 billion dollars in 2013 with the percentage of people who have cancer rising from 14.3% in 2009 to 18% in 2019. The health care industry was 6% of GDP in 2017 while Iran's efficient rank in the healthcare system was 30th in 2016 based on Bloomberg news and life expectancy is 75.5 and spending is 364 dollars per capita. The number of both state and private universities and the number of their students have increased dramatically. Figure 1 shows the number of physicians per 1000 persons in Iran.

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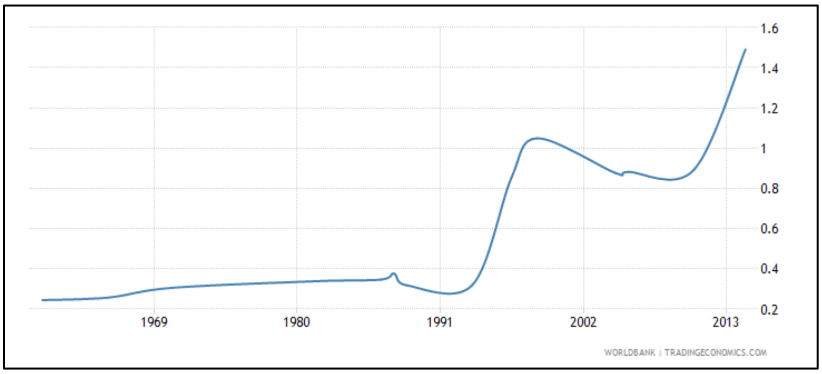


Figure 1: Number of physicians per 1000 persons in Iran (Trading economic website)

The healthcare industry in Iran includes both state and private hospitals. Figure 2 demonstrates the exposure to state hospitals.

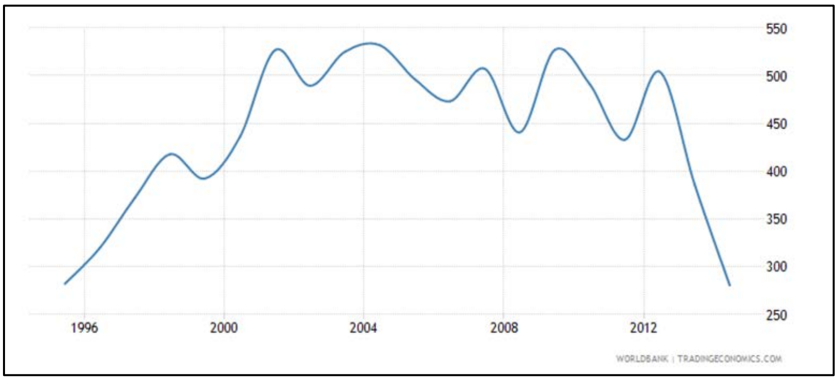


Figure 2: Exposure to state hospitals (Trading economic website)

In this research we mainly focus on maternity state hospitals in Tehran displaying Iran's new government vision of encouraging families to produce children because the rate of older people is mounting sharply and the birth rate is decreasing dramatically.

In other words, the rate of older people surpasses the birth rate. Consequently, focusing on this substance is crucial for significant notations. The fertility rate of women in Iran is depicted in figure 3.

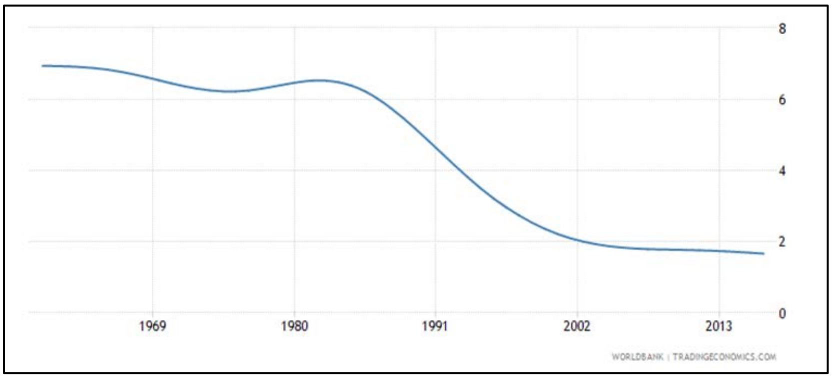


Figure 3: The fertility rate of women in Iran (Trading economic website)

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One of the Iranian government's pillars for growing the number of children in Iran is to put an emphasis on training skilled staff when children are born and caring for their mothers.

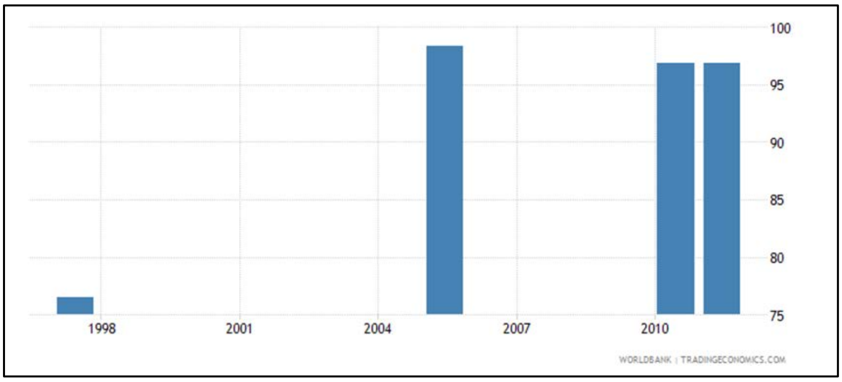


Figure 4: Birth attended by skilled health staff (Trading economic website)

Prenatal women need distinct attention both in capital cities and in small towns. In capital cities there are hospitals specialized in each branch of medical sciences and in small towns the government attempts to build a health center.

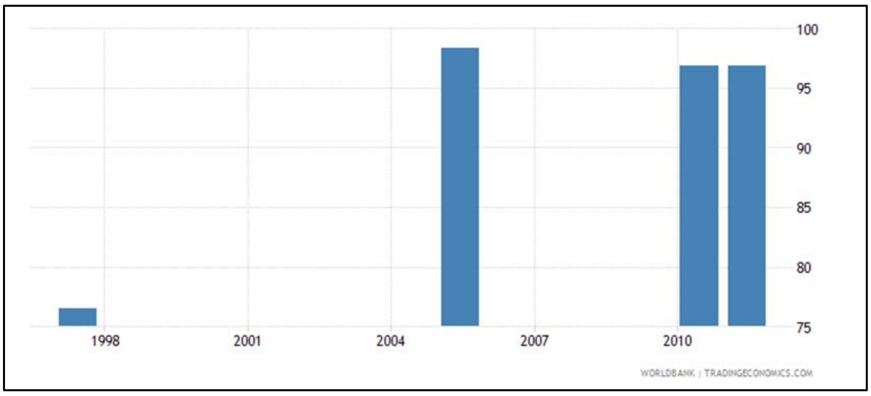


Figure 5: Pregnant women receiving prenatal care (Trading economic website)

Supply Chain Management (SCM) is the network of the process that resolves to satisfy customers by managing distribution, raw material, and factory, adding value to goods and services.

## 2.2. Supply Chain Contract Selection

Recent times are very crucial for service industries to provide legitimate solutions to the problem of closing contracts to do supply chain for companies. This work helps to ensure providing suitable services and goods for them. The interdependence and relationship between the supply chain members can be investigated in numerous conducts, including formal and informal, but to ensure proper delivery and delivery times, the buyer and the supplier need to reach an appropriate contract (Chen, & Özer, 2019).

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Due to the approach of companies and organizations to outsource the needs of goods and services, as well as selling products and services with specific terms and conditions in the form of contracts, managing these contracts is one of the most essential, central, and sensitive challenges. These organizations have become dynamic (Cai et al., 2017). They seem difficult given the variety of contracts, contract control, production, and management issues (Dubey et al., 2018).

Supply Chain Management is the evolutionary result of warehouse management. In the 1960s, experts were able to reduce their inventory by studying the internal relationship between warehousing and transportation and integrating them into what became known as distribution management studies (Kaya & Caner, 2018). Contract selection is one of the most critical supply chain decisions made by manufacturing companies in different industries.

Manufacturers usually have the option to choose from several types of supply contracts, including long-term, mid-term, and short-term contracts (Castañeda et al., 2019). While research has shown that the importance of such contracts for the supply chain is critical, there are only a few ways to optimally select contracts under different conditions, and few studies have been conducted in this area (Kouvelis & Zhao, 2015).

On the path of evolution, when adding manufacturing management, logistics, and order management issues to the logistics distribution concept, the current situation of the supply chain is the result of the interconnection of the different operational chains at the beginning of the customer as well as at the end of the customer (Meng et al., 2017). One effective way to improve supply chain performance is to coordinate supply chain members. In decentralized supply chains, each member of this supply chain decides on its own merits. In the absence of proper coordination mechanisms, conflicts of interest lead to decisions for the entire supply chain that seriously undermine the overall supply chain performance (Nie & Du, 2017).

Therefore, achieving a coordination mechanism is essential for encouraging members to make coordinated and aligned decisions with macro supply chain goals (Federgruen et al., 2019). Supply chain contracts are a useful mechanism for committing different members of a decentralized set to coherent and consistent behavior (Eckerd et al., 2016). Most of the research on supply chain contracts is based on research conducted in 2008 by Pasternak (Fan et al., 2019; Liu et al., 2015). The different types of supply chain contracts are as follows (Liu et al., 2015; Höhn, 2010; Tsay et al., 1999):

#### 2.2.1. Buy Back (Return) Contracts

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One of the cross-trade methods is that transactions are exported from one machine, manufacturing equipment, or a complete factory from one supplier to another, and in turn products that are produced, directly or indirectly, by these facilities for all or part of the cost of these facilities will be paid for a specified period of time.

In this Buy-Back (Return) contract, the products received directly or indirectly by the same facilities for all or part of the cost of the facilities are received within a specified time. In other words, the products exchanged in this cross-trade way are mutually related. The main objectives of these contracts are as follows:

1. Purchase of unsold goods at the end of the period by the retailer
2. Repurchase price lower than an initial sale price
3. Encourage the retailer to buy more at the beginning of the period
4. The need to have end-of-period inventory tracking capability
5. Acceptance of a part of the non-selling risk by the supplier
6. The likelihood of the retailer reducing the incentive to sell products before the end of the period

#### 2.2.2. Quantity Flexibility

In this contract, if the products are not sold by a certain date, the supplier will pay the cost in full. Unlike Buy-Back contracts, products are not referenced and a particular ceiling is defined for the number of products sold. Part of the not selling risk of the products lies with the supplier.

#### 2.2.3. Sales Rebate

The supplier rewards the retailer for passing the number of sales through a specified threshold. The purpose of the deal is to create an incentive mechanism to encourage retailers to sell more.

#### 2.2.4. Revenue Sharing

The supplier offers the retailer a lower price provided the retailer shares a portion of his income with the supplier. This type of contract allows two members to work together to determine the best order. The supplier in this contract receives two sources of money (direct sales and percentage of revenue).

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#### *2.2.5. Quantity discount*

A Quantity Discount contract is a type of price concession from companies given to customers who buy a large number of products with typically the higher the purchase the greater the discount. It encourages customers to increase their purchase from the same company or to purchase in advance.

### 2.3. Background

Talluri and Lee (2010) recommended a method based on mixed-integer programming for choosing the best contract for the supply chain. They presented specific insights to manufacturing managers on selecting the right contracts in the presence of market price uncertainty, supplier discounts, investment costs, and supplier capacity restrictions.

Nie and Du (2017) investigated quantity discount contracts in a dyadic supply chain that consisted of one supplier and two retailers. They displayed that supply chain contracts under behavioral concerns could not be coordinated with quantity discount contracts where price refund points depend on wholesale prices. So they proposed a hybrid approach to quantitative discount contracts with fixed costs.

Meng et al. (2017) provided a multi-agent model of four three-level supply chains that apply different types of hybrid contracts considering the effects of vertical and horizontal competition between the supply chains. The results of the simulation for this paper showed that the combined deals have no significant impact on the overall profits or profit stability of the supply chains with coordination, but different coordination mechanisms have different implications for the advantages and profit stability.

Cai et al. (2017) recognized the dynamic relationship under a revenue-sharing contract for supply chain management. These contracts help the SC members to get the optimal price, revenue-sharing ratio, inventory target, and subsidy rate as well as to commit inventory early. The mechanism proposed can better ensure SC collaboration and bring the SC to Pareto improvement by allowing members to negotiate, share profit, subsidies suppliers for their risks, and select from alternative contracts under each Vendor Managed Inventory setting.

Dubey et al. (2018) provided a model for choosing a suitable settlement with Key considerations for SCM agreements in the automotive industry. They offer an analytical framework on the effectiveness of supply chain contract selection with metrics (costs, risks, transaction costs, and stakeholder issues) that help model manager awareness of these

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concerns. They also suggest three factors (costs, benefits, and threats) that can affect these sustainable contracts.

Kaya et al. (2018) analyzed the optimal contract parameters for the manufacturer when designing a menu of contracts without exact knowledge of the supplier's capacity cost. They specified the optimal list of contracts intended for both high and low-cost suppliers and analyzed their results through numerical experiments.

They found that the optimal contract parameters determine the respective profits obtained by the supply chain members and found which contracts would be better to use for the companies depending on the system parameters in different settings by analyzing and comparing the efficiencies of the contracts. Chen and Özer (2019) specified the classification of contracts in the supply chain that facilitates the vertical sharing of information in a supply chain. They show that buy-back contracts perform significantly better than revenue-sharing or rebate contracts. Then based on studying the literature on this subject, sub-criteria were identified.

## 3. MCDM METHODS

### 3.1. Stepwise Weight Assessment Ratio Analysis (SWARA) Method

The SWARA method determines the weights of criteria based on comparison. For the computation of SWARA, weights are sorted based on the degree of importance.

Step 1: A score is given to each criterion. Scores are demonstrated as Comparative Importance of Average Value or $S_j$.

Step 2: Coefficient $k_j$ can be computed as follows:

$$k_j = \{1,\ j = 1\ s_j + 1,\ j > 1 \quad (1)$$

Step 3: The importance indicators of $q_j$ are calculated as follows:

$$q_j = \{1,\ j = 1\ \frac{k_{j-1}}{k_j},\ j > 1 \quad (2)$$

Step 4: The weights of criteria are computed as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \quad (3)$$

The relative weight of criterion j will be illustrated as $w_j$.

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### 3.2. Evaluation by an Area-Based Method of Ranking (EAMR)

One of the MCDM methods based on the decision matrix is EAMR. The first time, this model was introduced as EAMRT-2F. Later, this problem was solved with crisp data. The base of the problem is on beneficial and non-beneficial criteria. The methodological approach for EAMR is described as follows.

Step 1: Create the decision matrix $M_d$ as follows:

$$M_d = \left[M_{ij}^d\right] = \left[x_{11}^d \cdots x_{1m}^d \ \vdots \ddots \vdots \ x_{n1}^d \cdots x_{nm}^d\right], 1 \leq i \leq n,\ 1 \leq j \leq m,\ \ 1 \leq d \leq k \qquad (4)$$

Where k is the number of decision-makers, d is the decision-maker d$^{th}$, and $M_{ij}$ illustrates the criterion score of alternative i for criterion j of a Decision Maker (DM). n represents the number of alternatives and m the number of criteria.

Step 2: Calculate the decision matrix average

$$x_{ij} = (x_{ij}^1 + x_{ij}^2 + \cdots + x_{ij}^k)/\mathrm{k}$$

(5)

$$\underline{Y} = [\underline{x_{ij}}] \qquad (6)$$

Where $\underline{x_{ij}}$ shows value performance (criterion value) of alternative i and criterion j, and Y is the mean of the decision matrix, which is $1 \leq i \leq n, 1 \leq j \leq m.$

Step 3: The weighting matrix (weighting vector) $W_p$ is designed as follows:

$$W_p = [w_j^p]_{m\times 1} = [w_1^p\ w_2^p\ \vdots\ w_m^p] \qquad (7)$$

Where p is the index of the pth decision-maker and the respective weight of criterion $w_j^p$ is pointed out as j, $1 \leq j \leq m, 1 \leq p \leq k.$

Step 4: The mean weighting matrix (weighting vector) W̲ is computed as follows:

$$w_j = (w_j^1 + w_j^2 + \cdots + w_j^k)/k \qquad (8)$$

$$\underline{W} = [w_j]_{m\times 1} \qquad (9)$$

Step 5: Normal average decision matrix from Y, denoted as *N* is computed as follows:

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$$n_{ij} = \frac{x_{ij}}{e_j} \tag{10}$$

$$e_j = max_{i\in\{1,\dots,n\}}(x_{ij}) \tag{11}$$

$$N = [n_{ij}]_{n\times m} \tag{12}$$

Where $1\leq i \leq n, 1 \leq j \leq m$

Step 6: The normalized weights of the decision matrix *v* are found:

$$v_{ij} = n_{ij} \times w_j \tag{13}$$

$$V = [v_{ij}]_{n\times m} \tag{14}$$

Step 7: The normalized scores for beneficial criteria $(G_{+i})$ and non-beneficial criteria $(G_{+i})$ are calculated as follows:

$$G_{+i} = (v_{+i1} + v_{+i2} + \cdots + v_{+in}) \tag{15}$$

$$G_{-i} = (v_{-i1} + v_{-i2} + \cdots + v_{-in}) \tag{16}$$

$v_{+ij}$ and $v_{-ij}$ show normalized weighted values for beneficial and non-beneficial criteria, respectively.

Step 8: The rank of value (RV) is found based on $G_{+i}$ and $G_{-i}$ : $(1 \leq i \leq n)$. DMs are ranked alternatives based on normalized weights. This ranking is based on both beneficial and cost criteria. This ranking shows by $G_{+i}$ and $G_{-i}$.

Step 9: The appraisal score $(S_i)$ based on the rank values is computed as follows:

$$S_i = \frac{RV(G_{+i})}{RV(G_{-i})} \tag{17}$$

Where $S_i$ shows the alternative, that has the highest score

### 3.3. Problem Definition and Research Gap

The healthcare industry has a significant impact on the economy (Li & He, 2019). These impacts have led many people to dire circumstances or even death (Vandamme et al., 2019). Among survivors are prominent scientists, musicians and people active in many other professions. Broadly speaking, in Iran, numerous projects have been led to assist people to survive the fatal defects of the healthcare industry by providing access to standard medical aid in both big cities and small towns.

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One major project promoted by the Iranian government is related to the policy to increase Iran's population. Due to decreasing fertility levels (Zare et al., 2019). The population is ageing rapidly resulting in many problems including the gloomy prospect of workforce in the country (Tabatabaei & Mehri, 2019).

To counter such critical consequences, the Ministry of Health and Medical Education of Iran has put into practice various agendas not only to boost fertility levels. But also provide general health care for mothers (Bagheri & Saadati, 2019). As a direct result of such policies, many fertility centers have been founded in Iran in the recent years.

These medical centers have contracts with companies that provide their medical equipment. This equipment must be carefully examined and verified by these centers and other organizations involved prior to implementation, since they directly affect the health of patients and factors and methods that help decision-makers evaluate these contracts (Zare et al., 2019; Vandamme et al., 2019). Table 1 shows some of these methods.

Table 1: Methods by authors

| Author/authors | Method |
|---|---|
| TALLURI, LEE (2010) | Mixed-integer programming |
| NIE, DU (2017) | Dual-fairness |
| MENG et al. (2017) | Multi-agent model |
| CAI et al. (2017) | Dynamic relationship |
| LUO et al. (2018) | Stochastic and game theory |
| GHADGE et al. (2016) | Integer program |
| CHEN et al. (2018) | Principal agent model |

Even though numerous research identifications have been printed about supply chain contract selection based on both symmetric and asymmetrical information and diverse methods (Michalski et al., 2019), there is no evidence about the combination of SWARA and EAMR methods by hesitant fuzzy numbers. The combination of SWARA and EAMR methods causes a dramatic increase in accurate decision-making.

The SWARA method solved the problem by a rational dispute resolution method. Besides, the EAMR method has more reliability than other similar MCDM methods such as TOPSIS, MOORA, VIKOR and so on. The main contribution of this paper is the combination of SWARA, EAMR and using hesitant fuzzy set in the EAMR method. DMs tended to allocate exact scores to their preferences. On the other hand, if a group of DMs wanted to evaluate all alternatives, this work could lead to disputes among them. Therefore, reaching a consensus in decision-making is very hard. In this situation, fuzzy classic cannot be used, and only the technique that uses sets of membership function must be applied. One of these techniques is fuzzy hesitant set, which is very considerate to human preferences.

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# 4. RESEARCH METHODOLOGY

## 4.1. Research Procedure

The following steps were taken in this research for prioritizing manufacturing strategy CSFs:

Step1: Finding the CSFs: First, the CSFs were extracted from previous investigations and interviews with experts.

Step2: Selection and customization: These CSFs were customized by the Delphi method.

Step3: Primary weight: In this section, the SWARA method was used for finding the primary weight.

Step4: Hesitant fuzzy sets were used for transferring crisp data to fuzzy data to make a decision.

Step5: Ranking: the CSFs were ranked by the EAMR method.

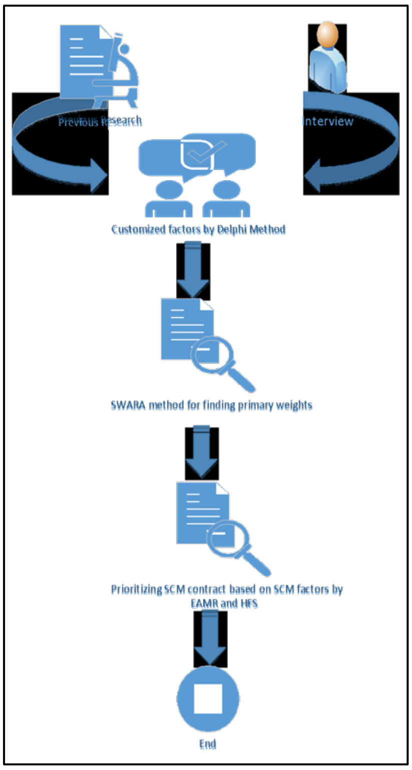


Figure 6: Research procedure

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### 4.2. Research Population

There are five state fertility centers in Tehran. Three of them are specialized in infertility, and two of them do other healthcare fertility-related services. These hospitals closed 19 SCM contracts with buyers.

### 4.3. Delphi method

The Delphi method examines the opinions of unidentified specialists and attaches them in printed, argument, and reaction arrangements on a precise schedule. This method proposes advance group conclusion-making by observing diverse interpretations from face-to-face communication. The technique for methodical for an assortment of decisions on an accurate theme channeling intended consecutive intervals, a banquet with potted evidence, and criticism of viewpoints consequent into earlier answers.

While the Delphi method contributes a regular schedule, thus helping to add expert thoughts, interval worsening can be supposed and high ambiguity and nebulousness still exist in specialist responses. The Delphi method as recap expert estimations in the range from 10 to 30 (Murry & Hammons, 1995). The Delphi method considered a tool for customizing CSFs based on experts. In this method, the questionnaire was created based on CSFs, and then experts tell their opinion based on Likert-scales (Strand et al. 2017).

For instance, when experts use a 5-point Likert- scale and if the average expert scores are less than four, the resulting CSF is eliminated. The number of experts in this method based on opinion researches must be between 5 and 15. The information of DMs is given in Table 2.

Table 2: The information of DMs.

| Expert | Education | Experience |
|---|---|---|
| Expert.1 | Ph.D. | 25 |
| Expert.2 | M.D | 23 |
| Expert.3 | MSc | 27 |
| Expert.4 | M.D | 20 |
| Expert.5 | M.D | 32 |
| Expert.6 | M.D | 29 |
| Expert.7 | M.D | 28 |

### 4.4. Critical Successful

Factors In this research, based on a previous study, 26 CSFs were successfully extracted. Then these CSFs were customized based on the Delphi method. Table 3 lists the computation of the customized CSFs.

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Table 3: Preview studies

| Number | criteria | code | references |
|---|---|---|---|
| 1 | Production facilities | PF | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 2 | Quality management intention | QMI | Fan et al., 2019; Liu et al., 2015; Höhn, 2010; Castañeda et al., 2019) |
| 3 | Quality system outcome | QSO | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Kouvelis and Zhao, 2015; Fan et al., 2019; Cai et al., 2017 |
| 4 | Claims | CL | Fan et al., 2019; Liu et al., 2015; Eckerd et al., 2016; Nie, DU, 2017 |
| 5 | Quality improvement | QI | Cai et al., 2017; Höhn, 2010 |
| 6 | Delivery | De | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Eckerd et al., 2016; Kaya, Caner, 2018; Nie, Du, 2017 |
| 7 | Response to claims | RC | Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 8 | On-time delivery | OD | Höhn, 2010; Sluis et al., 2016; Kaya, Caner, 2018 |
| 9 | Management and Organization | MO | Höhn, 2010; Tsay et al., 1999; Cai et al., 2017 |
| 10 | Organizational control | OC | Höhn, 2010; Tsay et al., 1999; Cai et al., 2017; Sluis et al., 2016 |
| 11 | Business plans | BP | Höhn, 2010; Cai et al., 2017; Sluis et al., 2016 |
| 12 | Customer communication | CC | Höhn, 2010; Tsay et al., 1999; Cai et al., 2017; Eckerd et al., 2016; Kaya, Caner, 2018; Nie, Du, 2017 |
| 13 | Internal audit | IA | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 14 | Data administration | DA | Fan et al., 2019; Liu et al., 2015; Höhn, 2010; Cai et al., 2017 |
| 15 | Constant trust | CO | Nie, Du, 2017; Kouvelis, Zhao, 2015; Eckerd et al., 2016; Fan et al., 2019 |
| 16 | Flexibility | FL | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 17 | Vision | VIS | Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017; Eckerd et al., 2016; Kaya, Caner, 2018; Nie, Du, 2017 |
| 18 | Financial position | FOP | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 19 | Health Safety Environment | HSE | Chen, Özer, 2019; Nie, Du, 2017; Eckerd et al., 2016; Fan et al., 2019 |
| 20 | Engineering coordination | ENC | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 21 | Relationships with public agencies | RPA | Kaya, Caner, 2018; Tsay et al., 1999; Ha, Krishnan, 2008 |
| 22 | Subcontractors Quality Assurance | SQA | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 23 | Turnover | TNO | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017; Kaya, Caner, 2018; Nie, Du, 2017; Eckerd et al., 2016 |
| 24 | Construction resources | COR | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 25 | Subcontracting strategies | SUS | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017 |
| 26 | Social impact of the proposal | SIP | Höhn, 2010; Tsay et al., 1999; Sluis et al., 2016; Cai et al., 2017; Kaya, Caner, 2018; Nie, Du, 2017; Eckerd et al., 2016 |
| 27 | Cost | COS | Caniato et al., 2015; Ghosh, Shah, 2015; Heydari et al., 2016; Mohammaditabar et al., 2016 |

The result indicates that among the 27 CSFs, 4 CSFs (Management and Organization, Organizational control, Business plans and Data administration) were eliminated by expert opinions. Table 4 evaluated factors of SCM contracts.

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Table 4: Customized SCM contract factors

| Code | Expert 1 | Expert 2 | Expert 3 | Expert 4 | Expert 5 | Expert 6 | Expert 7 | Average | Accept/Reject |
|---|---|---|---|---|---|---|---|---|---|
| PF | 4 | 5 | 3 | 4 | 4 | 5 | 3 | 4.00 | Accept |
| QMI | 3 | 5 | 4 | 5 | 3 | 5 | 4 | 4.14 | Accept |
| QSO | 5 | 4 | 5 | 4 | 3 | 5 | 4 | 4.29 | Accept |
| CL | 5 | 4 | 3 | 5 | 4 | 5 | 4 | 4.29 | Accept |
| QI | 5 | 4 | 3 | 5 | 4 | 5 | 3 | 4.14 | Accept |
| De | 5 | 4 | 3 | 5 | 4 | 5 | 3 | 4.14 | Accept |
| RC | 5 | 4 | 5 | 3 | 5 | 4 | 5 | 4.43 | Accept |
| OD | 5 | 4 | 3 | 5 | 4 | 5 | 5 | 4.43 | Accept |
| MO | 3 | 2 | 3 | 4 | 3 | 2 | 4 | 3.00 | Reject |
| OC | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 3.14 | Reject |
| BP | 3 | 2 | 4 | 3 | 2 | 3 | 4 | 3.00 | Reject |
| CC | 5 | 4 | 3 | 3 | 5 | 4 | 5 | 4.14 | Accept |
| IA | 4 | 5 | 3 | 5 | 4 | 3 | 5 | 4.14 | Accept |
| DA | 3 | 4 | 2 | 3 | 2 | 4 | 3 | 3.00 | Reject |
| CO | 3 | 4 | 5 | 4 | 5 | 3 | 5 | 4.14 | Accept |
| FL | 5 | 4 | 3 | 5 | 4 | 3 | 5 | 4.14 | Accept |
| VIS | 3 | 2 | 4 | 3 | 2 | 4 | 3 | 3.00 | Accept |
| FOP | 5 | 4 | 3 | 5 | 4 | 3 | 5 | 4.14 | Accept |
| HSE | 5 | 4 | 3 | 5 | 4 | 5 | 3 | 4.14 | Accept |
| ENC | 5 | 4 | 5 | 4 | 5 | 4 | 3 | 4.29 | Accept |
| RPA | 5 | 4 | 5 | 4 | 3 | 5 | 4 | 4.29 | Accept |
| SQA | 5 | 4 | 5 | 3 | 5 | 4 | 5 | 4.43 | Accept |
| TNO | 5 | 4 | 5 | 4 | 3 | 5 | 4 | 4.29 | Accept |
| COR | 5 | 4 | 3 | 5 | 4 | 5 | 3 | 4.14 | Accept |
| SUS | 5 | 4 | 5 | 3 | 5 | 4 | 5 | 4.43 | Accept |
| SIP | 5 | 4 | 3 | 5 | 4 | 5 | 5 | 4.43 | Accept |
| COS | 5 | 4 | 5 | 3 | 5 | 4 | 5 | 4.43 | Accept |

## 5. DATA ANALYSIS

### 5.1. Finding Primary Weights

After screening CSFs, the first primary weights are obtained based on the SWARA method as demonstrated below. Table 5 illustrates the analysis of the SWARA method.

Table 5: Illustrated analysis of the SWARA method

| Attributes | Comparative importance of average value ($s_j$) | Coefficient $K_j = S_j + 1$ | Recalculated weight $W_j = \frac{x_{j-1}}{K_j}$ | Weight $q_j = \frac{W_j}{\sum W_j}$ |
|---|---|---|---|---|
| Cost | - | 1 | 1.000 | 0.119 |
| Quality system outcome | 0.28 | 1.28 | 0.219 | 0.026 |
| Response to claims | 0.76 | 1.76 | 0.432 | 0.051 |
| On-time delivery | 0.56 | 1.56 | 0.359 | 0.043 |
| Flexibility | 0.21 | 1.21 | 0.174 | 0.021 |
| Financial position | 0.86 | 1.86 | 0.462 | 0.055 |
| Delivery | 0.76 | 1.76 | 0.432 | 0.051 |
| Production facilities | 0.17 | 1.17 | 0.145 | 0.017 |
| Claims | 0.65 | 1.65 | 0.394 | 0.047 |
| Health Safety Environment | 0.92 | 1.92 | 0.479 | 0.057 |
| Internal audit | 0.42 | 1.42 | 0.296 | 0.035 |
| Subcontractors Quality Assurance | 0.43 | 1.43 | 0.301 | 0.036 |

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| | | | | |
|---|---|---|---|---|
| Subcontracting strategies | 0.4 | 1.4 | 0.286 | 0.034 |
| Customer communication | 0.45 | 1.45 | 0.310 | 0.037 |
| Quality management intention | 0.89 | 1.89 | 0.471 | 0.056 |
| Relationships with public agencies | 0.71 | 1.71 | 0.415 | 0.049 |
| Turnover | 0.6 | 1.6 | 0.375 | 0.045 |
| Construction resources | 0.97 | 1.97 | 0.492 | 0.058 |
| Engineering coordination | 0.33 | 1.33 | 0.248 | 0.029 |
| Social impact of the proposal | 0.37 | 1.37 | 0.270 | 0.032 |
| Quality improvement | 0.84 | 1.84 | 0.457 | 0.054 |
| Constant trust | 0.67 | 1.67 | 0.401 | 0.048 |

### 5.2. Hesitant Fuzzy Sets

This is an extension of a fuzzy set, which prepares the degree membership of an element by representing several possible values between 0 and 1. The hesitant sets have more advantages in comparison with traditional fuzzy, particularly in group decision-making under uncertainty (Hu et al., 2018). These advantages prepare the opportunity to search for a decision in hesitant conditions. The hesitant fuzzy sets were introduced by Torra in 2009 and are widely applied in decision-making science. Hesitant fuzzy decision provides several possible values for degree membership of an element and is considered as a useful method to describe and deal with uncertain data. Suppose X is a reference set. Then each hesitant fuzzy set (HFS) is a function of h:

$$h : X \rightarrow \emptyset ([0,1]). \quad (18)$$

μ(xi) and v(xi) are the membership function and the non-membership function in the interval [0,1] and are accurate in the following condition for all values:

$$0 \leq \mu(xi) + v(xi) \leq 1 \quad (19)$$

Now we have π A (xi ) = 1- μ(xi)-v(xi) that πA (xi) is the uncertainty value of xi in the reference set A.

The point to be made here is that the number of HFE members can be different (Zhang et al., 2013; Xu et al., 2012).

Definition: A hesitant fuzzy element, such as H in A, is a function in HFS that is defined as a subset of h when the reference set is applied to the interval [0,1]. The hesitant fuzzy set is the generalization of intuitionistic fuzzy sets. This set is defined by Xu and Xia for convenience as follows:

$$H = \{\langle xih(xi)\rangle | xiX\rangle \quad (20)$$

h(xi) is a set of different values in the interval [0,1]. h(xi) is called the hesitant fuzzy element (HFE) in the set H.

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Definition 2: For a reference set X, if h(x) = {γ1, γ2, …, γl} is a hesitant fuzzy element with a set of possible values of with γ k (k=1,2,….,l) and 1 is a value of h(x), then the mean of h (x) in the HFE is defined by the following formula(3):

a) $h(x) = \frac{1}{l}\sum_{k=1}^{l} \gamma k$ b) (21)

A definition of the value operator and also variance operator is needed to compare the rules of hesitant fuzzy elements:

Definition 3: For per HFE, the value operator is as follows:

c) $s(h) = \frac{1}{lh}\sum_{\gamma \in h} \gamma$ d) (22)

It is clear that for two HF elements such as h1 and h2, if s(h1) > s(h2), then h1> h2, and if these two values are equal s(h1) = s(h2), then h1 = h2 (4).

Note: because the value operator of the two values is the same, there is no superiority between these two hesitant fuzzy elements. Moreover, another concept called the variance operator is defined:

Definition 4: For each HFE, the variance operator formula is as follows:

e) $\upsilon 1(h) = \frac{1}{lh}\sqrt{\sum_{\gamma i, \gamma j \in h} (\gamma i - \gamma j)2}$ f) (23)

For both HFE elements such as h1 and h2, if υ1(h1) > υ1(h2), then h1<h2.

Now we use a hesitant fuzzy set for the EMAR method.

Firstly, a decision- making matrix should be computed to obtain a set of values for the weights of the indices.

Step 1: compute the average of the decision matrix with the hesitant fuzzy values of the Sij matrix on the matrix of experts' opinion.

Now we calculate the Normal average decision matrix from Y in table 6 (the weight of criteria calculated with Swara):

Table 6: computing the Sij value of the results

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| | | Weights | Pro1 | Pro2 | Pro3 | Pro4 | Pro5 | Pro6 | Pro7 | Pro8 | Pro9 | Pro10 | Pro11 | Pro12 | Pro13 | Pro14 | Pro15 | Pro16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost | + | 0.119 | 0.1 | 0.1 | 0.7 | 0.5 | 0.8 | 0.4 | 0.9 | 0.4 | 0.3 | 0.6 | 0.2 | 0.7 | 0.9 | 0.8 | 0.2 | 0.5 |
| Social impact of the proposal | + | 0.032 | 0.7 | 0.3 | 0.4 | 0.5 | 0.2 | 0.1 | 0.3 | 0.6 | 0.2 | 0.1 | 0.1 | 0.7 | 0.1 | 0.1 | 0.5 | 0.6 |
| Subcontracting strategies | + | 0.034 | 0.3 | 0.6 | 0.6 | 0.2 | 0.5 | 0.2 | 0.1 | 0.4 | 0.5 | 0.9 | 0.8 | 0.7 | 0.4 | 0.4 | 0.9 | 0.1 |
| Construction resources | + | 0.058 | 0.8 | 0.1 | 0.7 | 0.1 | 0.9 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.2 | 0.8 | 0.5 | 0.5 | 0.1 |
| Turnover | + | 0.045 | 0.4 | 0.8 | 0.4 | 0.6 | 0.4 | 0.2 | 0.1 | 0.3 | 0.5 | 0.6 | 0.5 | 0.3 | 0.3 | 0.9 | 0.8 | 0.3 |
| Subcontractors Quality Assurance | + | 0.036 | 0.6 | 0.9 | 0.2 | 0.5 | 0.7 | 0.7 | 0.5 | 0.9 | 0.3 | 0.7 | 0.8 | 0.3 | 0.2 | 0.2 | 0.8 | 0.4 |
| Relationships with public agencies | + | 0.049 | 0.5 | 0.1 | 0.3 | 0.5 | 0.8 | 0.9 | 0.9 | 0.7 | 0.6 | 0.7 | 0.9 | 0.1 | 0.5 | 0.6 | 0.5 | 0.9 |
| Engineering coordination | + | 0.029 | 0.5 | 0.3 | 0.4 | 0.7 | 0.5 | 0.5 | 0.6 | 0.2 | 0.5 | 0.3 | 0.1 | 0.5 | 0.2 | 0.1 | 0.6 | 0.5 |
| Health Safety Environment | + | 0.057 | 0.8 | 0.1 | 0.1 | 0.3 | 0.6 | 0.3 | 0.4 | 0.9 | 0.6 | 0.7 | 0.7 | 0.3 | 0.6 | 0.3 | 0.8 | 0.9 |
| Financial position | + | 0.055 | 0.1 | 0.3 | 0.3 | 0.2 | 0.4 | 0.8 | 0.5 | 0.5 | 0.6 | 0.5 | 0.7 | 0.5 | 0.5 | 0.6 | 0.7 | 0.9 |
| Flexibility | + | 0.021 | 0.6 | 0.9 | 0.6 | 0.5 | 0.5 | 0.5 | 0.4 | 0.6 | 0.1 | 0.9 | 0.1 | 0.8 | 0.2 | 0.6 | 0.4 | 0.7 |
| Constant trust | + | 0.048 | 0.3 | 0.3 | 0.7 | 0.3 | 0.6 | 0.1 | 0.6 | 0.6 | 0.6 | 0.7 | 0.6 | 0.9 | 0.2 | 0.7 | 0.5 | 0.2 |
| Internal audit | + | 0.035 | 0.5 | 0.7 | 0.1 | 0.9 | 0.5 | 0.1 | 0.5 | 0.8 | 0.6 | 0.4 | 0.2 | 0.1 | 0.7 | 0.2 | 0.3 | 0.5 |
| Customer communication | + | 0.037 | 0.1 | 0.5 | 0.8 | 0.7 | 0.4 | 0.5 | 0.2 | 0.3 | 0.6 | 0.3 | 0.2 | 0.1 | 0.5 | 0.6 | 0.6 | 0.3 |
| On-time delivery | + | 0.043 | 0.8 | 0.1 | 0.6 | 0.4 | 0.1 | 0.3 | 0.3 | 0.7 | 0.8 | 0.3 | 0.1 | 0.9 | 0.7 | 0.2 | 0.3 | 0.3 |
| Response to claims | + | 0.051 | 0.9 | 0.6 | 0.8 | 0.5 | 0.8 | 0.1 | 0.3 | 0.3 | 0.4 | 0.8 | 0.1 | 0.3 | 0.1 | 0.2 | 0.6 | 0.3 |
| Delivery | + | 0.051 | 0.7 | 0.1 | 0.4 | 0.6 | 0.8 | 0.7 | 0.2 | 0.2 | 0.6 | 0.6 | 0.2 | 0.3 | 0.9 | 0.2 | 0.9 | 0.9 |
| Quality improvement | + | 0.054 | 0.6 | 0.5 | 0.4 | 0.3 | 0.7 | 0.4 | 0.6 | 0.3 | 0.5 | 0.9 | 0.5 | 0.2 | 0.1 | 0.9 | 0.1 | 0.2 |
| Claims | + | 0.047 | 0.8 | 0.2 | 0.1 | 0.5 | 0.9 | 0.7 | 0.2 | 0.7 | 0.8 | 0.2 | 0.5 | 0.8 | 0.7 | 0.6 | 0.5 | 0.8 |
| Quality system outcome | + | 0.026 | 0.6 | 0.9 | 0.5 | 0.1 | 0.1 | 0.1 | 0.4 | 0.9 | 0.4 | 0.9 | 0.8 | 0.5 | 0.8 | 0.1 | 0.6 | 0.6 |
| Quality management intention | + | 0.056 | 0.7 | 0.2 | 0.9 | 0.4 | 0.4 | 0.1 | 0.9 | 0.1 | 0.8 | 0.3 | 0.9 | 0.9 | 0.7 | 0.7 | 0.6 | 0.6 |
| Production facilities | + | 0.017 | 0.2 | 0.9 | 0.5 | 0.7 | 0.3 | 0.9 | 0.6 | 0.6 | 0.1 | 0.8 | 0.2 | 0.4 | 0.4 | 0.8 | 0.7 | 0.3 |

We can see the result in the Table 7.

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Table 7: Normal average decision matrix

| | | Weights | Pro1 | Pro2 | Pro3 | Pro4 | Pro5 | Pro6 | Pro7 | Pro8 | Pro9 | Pro10 | Pro11 | Pro12 | Pro13 | Pro14 | Pro15 | Pro16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost | + | 0.119 | 0.111 | 0.111 | 0.778 | 0.556 | 0.889 | 0.444 | 1.000 | 0.444 | 0.333 | 0.667 | 0.222 | 0.778 | 1.000 | 0.889 | 0.222 | 0.556 |
| Social impact of the proposal | + | 0.032 | 1.000 | 0.429 | 0.571 | 0.714 | 0.286 | 0.143 | 0.429 | 0.857 | 0.286 | 0.143 | 0.143 | 1.000 | 0.143 | 0.143 | 0.714 | 0.857 |
| Subcontracting strategies | + | 0.034 | 0.333 | 0.667 | 0.667 | 0.222 | 0.556 | 0.222 | 0.111 | 0.444 | 0.556 | 1.000 | 0.889 | 0.778 | 0.444 | 0.444 | 1.000 | 0.111 |
| Construction resources | + | 0.058 | 0.889 | 0.111 | 0.778 | 0.111 | 1.000 | 0.667 | 0.778 | 0.778 | 0.778 | 0.778 | 0.889 | 0.222 | 0.889 | 0.556 | 0.556 | 0.111 |
| Turnover | + | 0.045 | 0.444 | 0.889 | 0.444 | 0.667 | 0.444 | 0.222 | 0.111 | 0.333 | 0.556 | 0.667 | 0.556 | 0.333 | 0.333 | 1.000 | 0.889 | 0.333 |
| Subcontractors Quality Assurance | + | 0.036 | 0.667 | 1.000 | 0.222 | 0.556 | 0.778 | 0.778 | 0.556 | 1.000 | 0.333 | 0.778 | 0.889 | 0.333 | 0.222 | 0.222 | 0.889 | 0.444 |
| Relationships with public agencies | + | 0.049 | 0.556 | 0.111 | 0.333 | 0.556 | 0.889 | 1.000 | 1.000 | 0.778 | 0.667 | 0.778 | 1.000 | 0.111 | 0.556 | 0.667 | 0.556 | 1.000 |
| Engineering coordination | + | 0.029 | 0.714 | 0.429 | 0.571 | 1.000 | 0.714 | 0.714 | 0.857 | 0.286 | 0.714 | 0.429 | 0.143 | 0.714 | 0.286 | 0.143 | 0.857 | 0.714 |
| Health Safety Environment | + | 0.057 | 0.889 | 0.111 | 0.111 | 0.333 | 0.667 | 0.333 | 0.444 | 1.000 | 0.667 | 0.778 | 0.778 | 0.333 | 0.667 | 0.333 | 0.889 | 1.000 |
| Financial position | + | 0.055 | 0.111 | 0.333 | 0.333 | 0.222 | 0.444 | 0.889 | 0.556 | 0.556 | 0.667 | 0.556 | 0.778 | 0.556 | 0.556 | 0.667 | 0.778 | 1.000 |
| Flexibility | + | 0.021 | 0.667 | 1.000 | 0.667 | 0.556 | 0.556 | 0.556 | 0.444 | 0.667 | 0.111 | 1.000 | 0.111 | 0.889 | 0.222 | 0.667 | 0.444 | 0.778 |
| Constant trust | + | 0.048 | 0.333 | 0.333 | 0.778 | 0.333 | 0.667 | 0.111 | 0.667 | 0.667 | 0.667 | 0.778 | 0.667 | 1.000 | 0.222 | 0.778 | 0.556 | 0.222 |
| Internal audit | + | 0.035 | 0.556 | 0.778 | 0.111 | 1.000 | 0.556 | 0.111 | 0.556 | 0.889 | 0.667 | 0.444 | 0.222 | 0.111 | 0.778 | 0.222 | 0.333 | 0.556 |
| Customer communication | + | 0.037 | 0.125 | 0.625 | 1.000 | 0.875 | 0.500 | 0.625 | 0.250 | 0.375 | 0.750 | 0.375 | 0.250 | 0.125 | 0.625 | 0.750 | 0.750 | 0.375 |
| On-time delivery | + | 0.043 | 0.889 | 0.111 | 0.667 | 0.444 | 0.111 | 0.333 | 0.333 | 0.778 | 0.889 | 0.333 | 0.111 | 1.000 | 0.778 | 0.222 | 0.333 | 0.333 |
| Response to claims | + | 0.051 | 1.000 | 0.667 | 0.889 | 0.556 | 0.889 | 0.111 | 0.333 | 0.333 | 0.444 | 0.889 | 0.111 | 0.333 | 0.111 | 0.222 | 0.667 | 0.333 |
| Delivery | + | 0.051 | 0.778 | 0.111 | 0.444 | 0.667 | 0.889 | 0.778 | 0.222 | 0.222 | 0.667 | 0.667 | 0.222 | 0.333 | 1.000 | 0.222 | 1.000 | 1.000 |
| Quality improvement | + | 0.054 | 0.667 | 0.556 | 0.444 | 0.333 | 0.778 | 0.444 | 0.667 | 0.333 | 0.556 | 1.000 | 0.556 | 0.222 | 0.111 | 1.000 | 0.111 | 0.222 |
| Claims | + | 0.047 | 0.889 | 0.222 | 0.111 | 0.556 | 1.000 | 0.778 | 0.222 | 0.778 | 0.889 | 0.222 | 0.556 | 0.889 | 0.778 | 0.667 | 0.556 | 0.889 |
| Quality system outcome | + | 0.026 | 0.667 | 1.000 | 0.556 | 0.111 | 0.111 | 0.111 | 0.444 | 1.000 | 0.444 | 1.000 | 0.889 | 0.556 | 0.889 | 0.111 | 0.667 | 0.667 |
| Quality management intention | + | 0.056 | 0.778 | 0.222 | 1.000 | 0.444 | 0.444 | 0.111 | 1.000 | 0.111 | 0.889 | 0.333 | 1.000 | 1.000 | 0.778 | 0.778 | 0.667 | 0.667 |
| Production facilities | + | 0.017 | 0.222 | 1.000 | 0.556 | 0.778 | 0.333 | 1.000 | 0.667 | 0.667 | 0.111 | 0.889 | 0.222 | 0.444 | 0.444 | 0.889 | 0.778 | 0.333 |

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Then the normalized weights of the decision matrix v are found. The results are shown in table 8:

Table 8: Decision matrix v

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost | + | 0.013 | 0.013 | 0.093 | 0.066 | 0.106 | 0.053 | 0.119 | 0.053 | 0.040 | 0.079 | 0.026 | 0.093 | 0.119 | 0.106 | 0.026 | 0.066 |
| Social impact of the proposal | + | 0.032 | 0.014 | 0.018 | 0.023 | 0.009 | 0.005 | 0.014 | 0.027 | 0.009 | 0.005 | 0.005 | 0.032 | 0.005 | 0.005 | 0.023 | 0.027 |
| Subcontracting strategies | | 0.011 | 0.023 | 0.023 | 0.008 | 0.019 | 0.008 | 0.004 | 0.015 | 0.019 | 0.034 | 0.030 | 0.026 | 0.015 | 0.015 | 0.034 | 0.004 |
| Construction resources | + | 0.052 | 0.006 | 0.045 | 0.006 | 0.058 | 0.039 | 0.045 | 0.045 | 0.045 | 0.045 | 0.052 | 0.013 | 0.052 | 0.032 | 0.032 | 0.006 |
| Turnover | + | 0.020 | 0.040 | 0.020 | 0.030 | 0.020 | 0.010 | 0.005 | 0.015 | 0.025 | 0.030 | 0.025 | 0.015 | 0.015 | 0.045 | 0.040 | 0.015 |
| Subcontractors Quality Assurance | + | 0.024 | 0.036 | 0.008 | 0.020 | 0.028 | 0.028 | 0.020 | 0.036 | 0.012 | 0.028 | 0.032 | 0.012 | 0.008 | 0.008 | 0.032 | 0.016 |
| Relationships with public agencies | + | 0.027 | 0.005 | 0.016 | 0.027 | 0.044 | 0.049 | 0.049 | 0.038 | 0.033 | 0.038 | 0.049 | 0.005 | 0.027 | 0.033 | 0.027 | 0.049 |
| Engineering coordination | + | 0.021 | 0.012 | 0.017 | 0.029 | 0.021 | 0.021 | 0.025 | 0.008 | 0.021 | 0.012 | 0.004 | 0.021 | 0.008 | 0.004 | 0.025 | 0.021 |
| Health Safety Environment | + | 0.051 | 0.006 | 0.006 | 0.019 | 0.038 | 0.019 | 0.025 | 0.057 | 0.038 | 0.044 | 0.044 | 0.019 | 0.038 | 0.019 | 0.051 | 0.057 |
| Financial position | + | 0.006 | 0.018 | 0.018 | 0.012 | 0.024 | 0.049 | 0.031 | 0.031 | 0.037 | 0.031 | 0.043 | 0.031 | 0.031 | 0.037 | 0.043 | 0.055 |
| Flexibility | + | 0.014 | 0.021 | 0.014 | 0.012 | 0.012 | 0.012 | 0.009 | 0.014 | 0.002 | 0.021 | 0.002 | 0.019 | 0.005 | 0.014 | 0.009 | 0.016 |
| Constant trust | + | 0.016 | 0.016 | 0.037 | 0.016 | 0.032 | 0.005 | 0.032 | 0.032 | 0.032 | 0.037 | 0.032 | 0.048 | 0.011 | 0.037 | 0.027 | 0.011 |
| Internal audit | + | 0.019 | 0.027 | 0.004 | 0.035 | 0.019 | 0.004 | 0.019 | 0.031 | 0.023 | 0.016 | 0.008 | 0.004 | 0.027 | 0.008 | 0.012 | 0.019 |
| Customer communication | + | 0.005 | 0.023 | 0.037 | 0.032 | 0.019 | 0.023 | 0.009 | 0.014 | 0.028 | 0.014 | 0.009 | 0.005 | 0.023 | 0.028 | 0.028 | 0.014 |
| On-time delivery | + | 0.038 | 0.005 | 0.029 | 0.019 | 0.005 | 0.014 | 0.014 | 0.033 | 0.038 | 0.014 | 0.005 | 0.043 | 0.033 | 0.010 | 0.014 | 0.014 |
| Response to claims | + | 0.051 | 0.034 | 0.045 | 0.028 | 0.045 | 0.006 | 0.017 | 0.017 | 0.023 | 0.045 | 0.006 | 0.017 | 0.006 | 0.011 | 0.034 | 0.017 |
| Delivery | + | 0.040 | 0.006 | 0.023 | 0.034 | 0.045 | 0.040 | 0.011 | 0.011 | 0.034 | 0.034 | 0.011 | 0.017 | 0.051 | 0.011 | 0.051 | 0.051 |
| Quality improvement | + | 0.036 | 0.030 | 0.024 | 0.018 | 0.042 | 0.024 | 0.036 | 0.018 | 0.030 | 0.054 | 0.030 | 0.012 | 0.006 | 0.054 | 0.006 | 0.012 |
| Claims | + | 0.042 | 0.010 | 0.005 | 0.026 | 0.047 | 0.037 | 0.010 | 0.037 | 0.042 | 0.010 | 0.026 | 0.042 | 0.037 | 0.031 | 0.026 | 0.042 |
| Quality system outcome | + | 0.173 | 0.260 | 0.144 | 0.029 | 0.029 | 0.029 | 0.116 | 0.260 | 0.116 | 0.260 | 0.231 | 0.144 | 0.231 | 0.029 | 0.173 | 0.173 |
| Quality management intention | + | 0.044 | 0.012 | 0.056 | 0.025 | 0.025 | 0.006 | 0.056 | 0.006 | 0.050 | 0.019 | 0.056 | 0.056 | 0.044 | 0.044 | 0.037 | 0.037 |
| Production facilities | + | 0.004 | 0.017 | 0.009 | 0.013 | 0.006 | 0.017 | 0.011 | 0.011 | 0.002 | 0.015 | 0.004 | 0.008 | 0.008 | 0.015 | 0.013 | 0.006 |
| | | Pro1 | Pro2 | Pro3 | Pro4 | Pro5 | Pro6 | Pro7 | Pro8 | Pro9 | Pro10 | Pro11 | Pro12 | Pro13 | Pro14 | Pro15 | Pro16 |

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Now the normalized scores for beneficial criteria $(G_{+i})$ and non-beneficial criteria $(G_{-i})$ are calculated:

$$G_{+i} = (v_{+i1} + v_{+i2} + \cdots + v_{+in}) = \quad 1.234$$

$$G_{-i} = (v_{-i1} + v_{-i2} + \cdots + v_{-in}) = \quad 0.144$$

The rank of value (RV) is found based on $G_{+i}$ and $G_{-i}$ : $(1 \leq i \leq n)$. DMs are ranked alternatives based on normalized weights. This ranking is based on both beneficial and cost criteria shown by $G_{+i}$ and $G_{-i}$ .

The appraisal score $(S_i)$ based on the rank values is computed:

$$S_i = \frac{RV(G_{+i})}{RV(G_{-i})} \tag{24}$$

Table 9: The final rank for alternatives

| Alternatives | Rank | $S_i$ |
|---|---|---|
| Pro1 | 5 | 0.738 |
| Pro2 | 13 | 0.636 |
| Pro3 | 9 | 0.692 |
| Pro4 | 15 | 0.528 |
| Pro5 | 10 | 0.691 |
| Pro6 | 16 | 0.496 |
| Pro7 | 12 | 0.678 |
| Pro8 | 2 | 0.810 |
| Pro9 | 8 | 0.697 |
| Pro10 | 1 | 0.886 |
| Pro11 | 6 | 0.730 |
| Pro12 | 11 | 0.681 |
| Pro13 | 3 | 0.798 |
| Pro14 | 14 | 0.595 |
| Pro15 | 4 | 0.764 |
| Pro16 | 7 | 0.729 |

### 5.3. Sensitivity Analysis

In this section, the result of EMAR is compared with other similar methods such as TOPSIS, VIKOR, and WASPAS. All of these methods are related to the decision matrix methods family. The Person coefficient technique was used for finding the relationship between the results of each. This coefficient shows us how much the result was similar to each other.

Table 10: The effect of ranking the alternatives by these methods.

| | WASPAS | TOPSIS | VIKOR |
|---|---|---|---|
| Pro1 | 1 | 3 | 1 |
| Pro2 | 14 | 8 | 7 |
| Pro3 | 9 | 12 | 12 |
| Pro4 | 10 | 10 | 11 |
| Pro5 | 5 | 11 | 9 |

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| | | | |
|---|---|---|---|
| Pro6 | 16 | 9 | 10 |
| Pro7 | 15 | 16 | 16 |
| Pro8 | 6 | 5 | 6 |
| Pro9 | 3 | 1 | 3 |
| Pro10 | 4 | 6 | 5 |
| Pro11 | 7 | 4 | 4 |
| Pro12 | 13 | 13 | 14 |
| Pro13 | 12 | 15 | 15 |
| Pro14 | 11 | 14 | 13 |
| Pro15 | 2 | 2 | 2 |
| Pro16 | 8 | 7 | 8 |

Figure 7 shows the ranking of these alternatives by these methods.

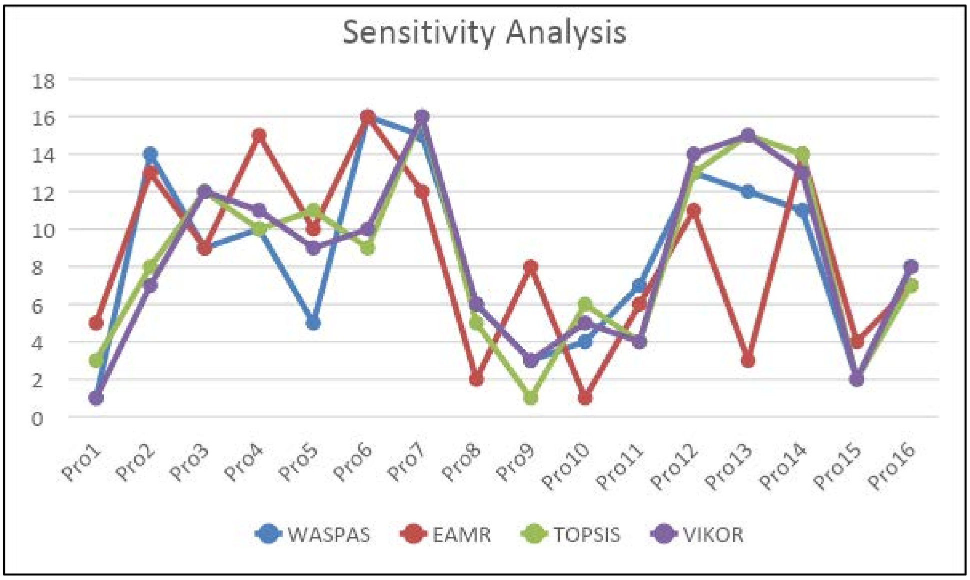


Figure 7: The ranking of these alternatives by these methods

Table 11 illustrates the Pearson coefficient between EAMR and other methods. When the Sig of this comparison is less than 0.05, this means that there is a relationship between these results, and when the Sig is higher than 0.05, this shows that there is no evidence for claiming that there is a relationship between these results.

Table 11: The Pearson coefficient between EAMR and other methods

| | TOPSIS | VIKOR | WASPAS |
|---|---|---|---|
| EAMR(Coefficient) | 0.459 | 0.485 | 0.668 |
| Sig | 0.074 | 0.057 | 0.005 |

The result indicates that among TOPSIS, VIKOR, and WASPAS methods solely, the result of the WASPAS method had more similarity with the EAMR method and that the rest of processes did not have similarity with the EAMR method.

## 6. CONCLUSIONS

Nowadays in some countries where the fertility rate is low, the government's plan is to increase this rate, so they encourage mothers to get pregnant, but this work needs some pre

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requisites such as a hospital must be equipped and have expert physicians. Many instruments are required for children to be born and hospitals must provide their services on time and with high quality. To do this work, they close SCM contracts, but these contracts must be evaluated for both essential factors to be onetime and a variety of materials. This work helps hospitals make a decision accurately. In this research, first all CSFs for evaluating SCM contracts were extracted by Delphi method.

Among 27 factors, four factors were eliminated by DMs viewpoint. Then these factors were ranked by the SWARA method. Among these factors, the cost factor is the highest factor among them which means that for hospitals, the cost factor is vital for their evaluation. Since the EAMR method is used for ranking contracts based on CSFs and this method is a kind of decision matrix method, it needs primary weights.

The SWARA method was applied for obtaining the primary weights and then this research considered 16 SCM contracts for governmental fertility centers for evaluation using the EAMR method. Reaching decisions in this environment, however, is difficult because everything is changing all the time, so hesitant fuzzy sets are used. The result indicates that hospitals based on these CSFs must be selected contracts.

A proposal for future researches to use the SWOT matrix and quantitative decision-making methods to select contracts and also to measure the factors affecting the DEMATEL method.

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