Decision Analytics Journal 4 (2022) 100124

Contents lists available at ScienceDirect

Decision Analytics Journal

journal homepage: www.elsevier.com/locate/dajour

A fuzzy soft approach toward power influences in supply chain performance in Electronics Manufacturing Industry

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ARTICLE INFO

Keywords:
Fuzzy soft set
Supply chain management
Power
Best-Worst Method (BWM)
Performance measurement

ABSTRACT

Companies create supply chains (SC) to gain added value, but collaborative relationships do not mean they all receive a balanced share of this value due to power asymmetry. The success of an SC depends on its ability to deliver the required products/services to the customer with specific quality and characteristics on time and in the right place. We study SC performance measures as the decision-making criteria given the primary goal of profit maximization in SC management. Different kinds of power are classified, and a process is proposed to choose the most appropriate form of power for companies at each level of SC. Using a mixed Best-Worst Method (BWM) Fuzzy soft set approach, the suitable power form for each company is determined. The results show there is not one best power form to be prescribed for all firms, so each company may need different strategies to achieve different power positions depending on its relationship with other SC echelons. We also present a sensitivity analysis to demonstrate the robustness of our proposed approach.

1. Introduction

Supply chain management (SCM) is still in the core of attention after decades of its invention. Because the nature of business competition avoids organizations' independence. All around the SCM literature we can find emphasis on collaboration and cooperation [1–3] in fact they act as glue in the SCs which keep individual companies together, but these are not the only factors. SCs are structured on power asymmetry [4]. Companies create SCs to gain more added value but collaborative relationships do not mean that all of them receive a balanced share of this value and this is due to power asymmetry [5–7]. This is what practitioners are always worried about and has attracted academic interests as well. If we see SC as an organic system [8] then we can define and expect many other behavioral reactions from any echelon in a considered SC, such as conflicts or separation due to the sense of power asymmetry or injustice. From a political perspective, power is the ability to get things done when goals conflict. And we know that in SCs, power is shared between echelons because no one person controls all the desired activities in the whole SC. The point is that power is not a zero-sum game i.e., when one gains power, it does not imply that the other loses the same amount of power. This can modify the unpleasant sense of power definition in SC management while all SC members wish and try to gain the power. Another considerable point is that all the members does not need same form of power toward all other SC members, e.g., while one company can increase its benefit using reward power, the opposite company may achieve its goals by referent power.

As Brito and Miguel [9] emphasize it is important to think about some factors to tighten the collaborative connections between organizations when we know that unfair value sharing among SC layers prevent or decrease cooperation [10,11]. In this research we study the need for each of power forms in organizations according to their role and position in the SC, toward other SC elements.

Power is very effective factor in SCM because if an organization does not have power, it cannot influence the SC strategies and has to follow other organizations' plans [4]. Each of the organizations in a SC has a kind of power to some extend but the fact is that if more powerful player tries to force other players, soon or late others will find a substitute for that and firm in the SC will disappear or because of lack of collaboration the design of SC will change so it is very critical for managers and decision makers to know what kind of power is needed in association with each of the companies in their SC so that they can define strategies to achieve that power in their business relationships. For example as indicated by several scholars such as Hunt and Nevin [12] and Lusch [13] punishment as a symbol of coercive power is positively related to conflicts in SCs but causes brokers' satisfaction.

Cooperation of different companies in a SC framework is usually based on contractual or relational connections, which is formed by a power based transaction; contractual contact is defined by a formal contract for a specific time duration, usually short time but relational

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https://doi.org/10.1016/j.dajour.2022.100124
Received 7 August 2022; Received in revised form 24 August 2022; Accepted 3 September 2022
Available online 7 September 2022

contact is constructed on behavioral concepts such as trust which is mutual feeling between two parties and causes long term cooperation during which each party tries to share resources, knowledge and benefits [1,9,14,15]. But some scholars believe sometimes there is a mixed or middle term, like contractual relational contacts [7,16–18]. To be able to decide which condition is more appropriate for any company, it is suggested that companies assess their connection position periodically and change/keep it according to strategies [6]. This means companies should analyze and know their role in the game of power.

In the competitive world of business, the SC is seen as an arena for conflicts, while viewing business as a political system. So, it is important to understand the various echelons, their relative power and influence, their interests and the dominant coalitions in the SC. The leader in such a system is seen as an astute negotiator who forges right coalitions while identifying and leveraging interests of various echelons. In the context of risk management, the political lens is very important, especially if the SC has organizations rigidities in place. In the context of change management, right coalitions can make the make or break difference. As far as we know this is the first study which tries to recognize all possible power forms and choose the most appropriate one for each company according to its position in the SC, considering the performance measures as decision criteria.

The existence of an SC is based on its ability to prepare the required products/ services to the customer with the specified quality and characteristics on time and at the right place. So, considering the importance of this goal we use SC performance measures as decision making criteria while ranking the power forms for studied SC, because the main managers' concern in real world is their organization and SC performance.

Douglas and Terrance [19] studied the role of performance measures on SC success, they believe that applying suitable SC performance measures can avoid failure while controlling service level. This motivated us to find a complete list of performance measures and choose among them by the help of SC experts.

Another challenge is the decision-making method. Analytic Hierarchy Process (AHP) is one of the most famous utility-based decision-making techniques that applies pairwise comparisons to calculate the criteria weights [20]. As inconsistency is a part of comparison nature, the inconsistency is inevitable in pairwise comparison matrix and may cause inaccurate or deviated answers [21].

Many other methods also use such comparisons in shape of decision matrix, such as PROMETHEE. In real examples which usually contain many alternatives or criteria, the calculations will increase exponentially and decrease the consistency of comparisons. For instance, in a problem with 6 criteria and 6 alternatives, experts should reply 105 times of pairwise comparisons [22] so we decided to choose best worst method (BWM) to select most suitable decision criteria among all founded SC performance measures, because BWM effectively decreases the calculations of pairwise correlations and is great in keeping up with consistency between decisions.

Then in next step we preferred to use a fuzzy approach for finding best power form, because talking about power forms and comparing them are more linguistic than quantitative so it was not easy for experts to choose among them by crisp numbers. Since introduction of fuzzy concept for real life problems that require uncertain, imprecise or subjective data, different kinds of fuzzy numbers and sets are defined and extensively have been used in decision making problems under uncertain situations.

Many scholars presented extensions of fuzziness such as hesitant fuzzy sets, soft fuzzy sets and intuitionistic fuzzy sets. Set-valued fuzzy sets can be regarded as type-2 fuzzy sets. Soft set theory is known as a mathematical approach toward uncertainties which is free from the inadequacy of parameter tools. In fact, in soft sets the membership function which is main problematic concept in fuzzy set theory, does not arise so makes it more convenient and easier to use practically, that is why we decided to use this approach here.

The main contributions of this study are first the new approaches toward power concept in SCM, its role and effects on SC relations and cooperation, second is the new suggested decision-making method which can be used in situations where we have several criteria and need to filter them somehow to choose most appropriate ones as decision criteria for decision makers. In next step respondents can easily answer questions in fuzzy manner by linguistic answers instead of numbers which might be difficult or time consuming in qualitative topics like power concept.

The structure of this paper is as follows. In Section 2 a review on studies about power in SCM, SC performance measures, BWM and soft fuzzy sets is presented. Section 3 contains our problem definition where firstly we present the problem then explain the research methodology and in Section 4, we apply the decision-making method and in Section 5, we present a sensitivity analysis to demonstrate the robustness of our proposed approach then discuss about findings and suggest managerial insights in Section 6. At the end, last section contains the conclusion.

2. Literature review

2.1. Power in SCM

General power definitions come from various schools of thought [23]. Power is a necessary conflict while plans or interests are not homogeneous, where one loses and one gains [24]. Power is also defined as someone's ability to dominate other's resistance to obtain a desired result [25]. One of the first scholars who talked about different bases of power were French et al. [26], they introduced reward, coercive, legitimate, referent and expert as bases of power. They defined bases of power as those characteristics of an identity which give it the ability to influence others. After that many different clusters and concepts were derived for this topic which shows that power is a challenging concept [27]. It appears logical that if power is issue-specific rather than pervasive, then sources of power should also be considered as issue-specific. The literature on this topic is also very troublesome, beside many studies, it is still a vague, confusing and complicated to be clearly defined [28,29]. Nevertheless, Dahl [30] has a practical definition for power; person A has power over person B when he can make B do something that he would not do at his own will. Based on this definition, Siawsh et al. [23] characterize power as the capacity to accomplish planned outcomes, yet in addition to control others' practices and additionally activities in spite of opposition.

The study of power within SCs become more complex. Cox [31] believes power is at the core of all business-to-business connections. Enterprises owning necessary resources get power over SC partners who need these resources. On the one side, enterprises who need these resources try to accomplish a significant degree of ability to acquire their need and deal with the vulnerabilities of their external environment [32]. Some studies focus on marketing behaviors and strategies in SC relations such as push–pull strategies [33,34]. Some have classified power into reward-mediated, coercive-mediated and non-mediated [4,35]. Analyzing all classifications, we concluded to six power forms considering different bases of power in general which can be studied in social relations as well as organizational relations, these forms along with definition of each, are displayed in Table 1.

2.2. Supply chain performance measures

One of the fundamental standards of any administration framework is performance management, SC management is not an exception. For performance management we need performance measures [43]. Researchers believe that performance measures can improve the communication quality between practitioners in a system and also lead to more supportive cooperation [44,45]. First studies about SC performance measures started by Chow et al. [46], they introduced some measures for logistics system performance which is a traditional version of SC. After that the Supply Chain Council (SCC) fostered the Supply

Table 1
Forms of power.

FORM	DEFINITION	REFERENCE
Coercion	The willingness to inflict negative consequences for non-compliance	[26,36,37]
Reward	Arrangement of a positive result, in return for wanted conduct	[26,36,37]
Legitimate	Disguised worth that a firm is committed to acknowledge another association's impact	[25,26,38,39]
Information	Tendency of sharing information and know-how	[40]
Expert	attribution of mastery to another company	[26,41]
Referent	The craving to relate to and be like an exceptionally regarded company	[26,38,42]

Chain Operations References (SCOR) structure in 1996. At first, SCOR included four business processes: plan, source, make, and convey. Return, the fifth cycle, was added in 2001 [47].

Defining or finding appropriate performance metrices is crucial and practitioners usually complain about the lack of guidelines in this regard, it is more critical when comes to SCs because it is a combination of individuals [48]. We overview some suggested measures in the literature, diversity of used measures in different studies show that both academicians and practitioners know that a set of measures cannot be prescribed for all SCs. That is why we will also make a list of studied measures in previous researches during last decade in Table 1 and find the appropriate set of measure for our study by the help of SC experts.

One of the most practical methods is The Balanced Scorecard which contains four performance areas: monetary, client, inside business and development and learning [49]. Many other academicians and practitioners developed methods and frameworks based on different group of measures. Otley [50] is of them who designed a framework which contains five performance scopes: the company's destinations, techniques and plans to accomplish them, target-setting, motivation and award instruments and data criticism circles. Beamon [51] preferred measures in assets, result and adaptability. Gunasekaran et al. [52] is another example that suggested a model for SC performance measurement considering metrics in arranging, obtaining, making/collecting and conveyance/clients. Chan [53] explained SC measure in two group of subjective (for example consumer loyalty, adaptability, data and material stream mix, and compelling gamble the board) and quantitative (for example cost, deals, benefit, stock speculation, profit from venture and the proportion of net benefit to the capital utilized to create benefit). In another work Chan and Qi [54] explain that SC performance is estimated in distorted and counterproductive terms, in another words they center around minimizing individual expenses however not to maximizing the worth to the consumer. Gunasekaran et al. [55] mentioned measures related to strategic planning, replenishment arranging, vendors, manufacturing and distribution.

Shepherd and Günter [56] worked on a broad scientific categorization of measures: the cycles (plan, source, make, convey or return), key performance indicators (cost, time, quality, adaptability or creativity), and quantitative or subjective measures. Askariazad and Wanous [57] prepared a set of monetary, non-monetary, qualitative, quantitative, input and output metrices for SC performance measurement. Whicker et al. [58]proposing measures like lead time, replenishment rate or on-time performance argue that usually cost is used in SC concept so a special focus is needed on cost-based approaches. Carvalho et al. [59] also suggested some measures which are summarized in financial, environmental, flexibility, innovation, integration and operational areas. Ainapur et al. [60] believe that Key Performance Indicators should be simple, easy to measure and intuitive and define their used measures under SCOR framework. Balfaqih and Yunus [61] tried to measure SC performance by utilizing a blend model of a unified system joining SCOR Model and system approach model, they chose quality, time, data, adaptability, and coordination as their criteria. Use of SCOR metrices can be seen in many other papers such as Lima-Junior and Carpinetti [62]; Patil [63] and Ayyildiz and Gumus [64].

Gong and Yan [65] defined logistics service SC processes in the overall process, customer service, and corporate management parts and selected metrices based on this definition. Sahu et al. [66] tried a new view to SC, they developed an evaluation index system as a staggered various leveled system toward assessing an "appraisement list" from the plan of estimating and observing resilient execution. Such studies have attracted more attentions in recent years, Yusuf et al. [67] is another example which designed a new platform to study the impacts of agile activities on sustainability performance indexes, hence they explored the relations between agile activities, sustainable activities, operational performance targets and sustainable performance of companies using different group of metrices related to each of mentioned fields.

In a new study Simão et al. [68] developed a new SC performance measurement system called the Triple E performance assessment system, which assesses three aspects together: environmental, efficacy and efficiency impact.

We prepare a list of measures mentioned in researches during last decade, 2010–2021, in Table 2. Some of which are explained above but to avoid repetition and expansion of literature review section, we summarize more studies in Table 2.

2.3. BWM in decision making

After the first paper introducing the BWM, this method has attracted many researchers' attention because it covers some weak points of famous methods by the efficiency in lessening the calculations of pairwise correlations and the great presentation in keeping up with consistency between decisions [100,101]. Rezaei [102] proposed his new Multiple Criteria Decision Making (MCDM) approach, named BWM claiming that the complicated pairwise comparisons that are done by experts in most common MCDM models are due to the unstructured way of doing such comparisons which is unnecessary. He generated a five-step method, in first step a bunch of decision criteria are determined. The best criterion C_B and the worst criterion C_W among all the decision criteria are chosen by the decision maker which are the most significant and least significant standards among every one of the criteria. Then a pairwise correlations between C_B and the rest of measures are formulated and resolved. Finally the Best to Others (BO) vector is found as $BO = (a_{B1}, a_{B2}, \dots, a_{Bj}, \dots, a_{Bn})$ where a_{Bj} shows the preference degree of the C_B over criterion C_j, and $a_{Bj} \geq 1, j = 1, 2, \dots, n; j \neq B$. In next step the same is done for C_W. Then, the Others to Worst (OW) vector will be achieved as $OW = (a_{1W}, a_{2W}, \dots, a_{jW}, \dots, a_{nW})^T$ where a_{jW} shows the preference degree of criterion C_j over the worst criterion C_W, and $a_{jW} \geq 1, j = 1, 2, \dots, n; j \neq B, W$. In the BWM, for n criteria, n−1 seasons of pairwise examinations are done in the ref-

Table 2
The SC performance metrices.

Measure	Definition	References
Asset Management Efficiency	The viability of an association in overseeing resources for demand fulfillment. This incorporates the administration of fixed and working capital	[63,64,69,70]
Collaboration with Stakeholders	Sharing the obligation of trading normal preparation, the board, execution, and performance assessment data	[67,71–73]
Cost of Products	Cost of goods sold	[61,63,64,67,71,74–82]
Customer Satisfaction	Customer's impression of the service got from the vendors to satisfy supply chain management goals	[65,67,71,72,76,77,81,83–89]
Cycle Efficiency	Efficiency is an internal standard of performance and is approximately a construct "for doing the things right".	[68,78,88,90]
Delivery Reliability	Conveying the right item, to the perfect locations, at the right time, in the right condition and bundling, in the right amount, with the right documentation, to the right client	[69,71,75,77,81,91]
Environmental Performance	Includes emissions, energy use and recovery, spill and leak prevention and discharges	[66–69,73,82,84,87,92,93]
Financial Performance	Contains pre-tax return on assets (ROA), return on investment (ROI) and return on sales (ROS)	[67,72,73,75,76,79,85,89,94]
Flexibility	The agility of a SC in reacting to marketplace changes to acquire or keep competitive advantage	[61,65,67,77,83,85,91,94,95]
Human Resources Performance	Alludes to workers' performance excellence in gathering anticipated levels, or execution objectives, on different SCM-related efforts and practices	[67,71,73,76,78,82,88,96]
Information Security	Lies in the coordination of people, processes and technology and consideration of technical, formal and informal controls of the information system	[65,71,83,85,90,94]
Innovativeness	The reception of a thought or conduct whether relating to a gadget, framework, process, strategy, program, item or administration that is new to the firm	[67,76,77,79,83,85,94]
Internal Process Performance	Speed, quality, cost and flexibility of supply chain process improvements	[72,76,77,79,85,89,90]
Inventory Levels	The sum and area of each raw material, work in process, and final product stockpiling	[71,80]
Lead Time	The time that passes from the beginning of a cycle until its end	[61,74,76,80,85,88,91,94,97]
Productivity	Prescribed output to the resources consumed	[74,80,81,84,88,98]
Quality	Quality of products	[61,67,74,77,79,80,85,87,91,94]
Reliability	The likelihood of the unblemished and faultless exhibition of the SC for a specific and pre-planned timeframe	[62,64,67,88]
Resources Efficiency	The efficiency of resource use	[65,67,79,86,87,90,91,98,99]
Responsiveness	The speed at which a SC gives items to the client	[63–65,71,73,74,79,81,83,85–87,89,91,94,98]
Technological Efficiency	Correctness of the used technology, materials selection and technological parameters selection	[71,73]

erence correlations in regards to the best criterion and similar number of examinations for the worst criterion. We exclude the best criterion while comparing with the worst criterion since the correlation between the best basis and the worst measure has been done during the time spent the reference examinations with respect to the best model. Consequently, in the structure of BWM, we just need to do 2n−3 seasons of pairwise correlations.

In the next step, a minimization model is intended to compute the weight of the different markers with the goal that the ideal weights of criteria fulfill $\frac{w_B}{w_j} = a_{Bj}$ and $\frac{w_j}{w_W} = a_{jW}$. In another word the maximum absolute differences $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jW}\right|$ should be minimized. In form of optimization model, it can written as [103]:

$$\begin{aligned} &\min \varepsilon \\ &s.t. \quad \sum_j w_j = 1,\ w_{\ j} \geq j; \quad for\ all\ j \\ &\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \varepsilon \\ &\left|\frac{w_j}{w_w} - a_{jw}\right| \leq \varepsilon \end{aligned} \tag{1}$$

Where ε denotes the maximum absolute differences defined above. By consideration of the ε value, consistency rate can be determined. The closer to zero, the more consistent comparisons and the closer to one, the less consistent comparisons. Consistency Index which is used to determine consistency rate can be reached by applying values shown in Table 3. The Consistency rate (CR) is then calculated by $CR = \frac{\varepsilon}{Consistency\ Index}$.

After first paper about BWM in 2015, this method has been used by Rezaei et al. [104] developing a supplier selection method by BWM in food industry. Then Ahmadi et al. [105] applied it to analyze the SC social sustainability in manufacturing companies. Next year Salimi and Rezaei [106] employed BWM in performance measurement model for a high-tech company R&D department in the Netherlands. Again in another paper Rezaei et al. [107] used BWM to design a weighted logistics performance index. Gupta [108] developed a BWM-VIKOR model to prioritize the service quality of the airline industry using customers' needs. Brunelli and Rezaei [103] introduced a new measurement into the system of the BWM. The elective measurement does not change the first thought behind the BWM and can be optimized as a linearized problem. Kheybari et al. [109] used BWM based on dimensions of sustainability to choose best facility location for the

Table 3
Consistency index.

Number	1	2	3	4	5	6	7	8	9
Consistency index	0	0.44	1	1.63	2.3	3	3.73	4.47	5.23

production of bioethanol in Iran. Zolfani and Chatterjee [110] also employed a sustainability based BWM model for evaluating the design of household furnishing materials, they represented a comparative study of the step-wise weight assessment ratio analysis (SWARA) and BWM. In 2020, Rezaei introduced a proportion, called concentration ratio, to check the convergence of the ideal spans acquired from the nonlinear BWM. He examined the connection between the concentration ratio and the consistency ratio and tracked down that the concentration ratio alongside the consistency ratio of the model gives upgraded bits of knowledge into the unwavering quality and adaptability of the aftereffects of BWM [111].

Liang et al. [112] proposed an information based consistency estimation to find the inconsistency, they established edges for the consistency proportions utilized in BWM and provided an algorithm for obtaining the thresholds. Dong et al. [113] presented a new fuzzy best-worst strategy (BWM) in light of triangular fuzzy numbers, they proposed the ideas of fuzzy consistency list and fuzzy consistency ratio. They built four linear programming models to find optimum fuzzy weights. As a young MCDM method, BWM has attracted too much attentions among academicians as well as practitioners and the number of publications using this method is too high but to our knowledge till date no one has applied this method along with fuzzy soft sets to prioritize alternatives. So, we work on this gap and propose a new method to rank and choose the best power form in the SC.

2.4. Fuzzy soft sets

At first, we need to introduce fuzzy soft sets (fs-sets). U is an initial universe of objects, E is a set of attributes, $P(U)$ is the power set of U and $A \subseteq E$.

A soft set F_A over U is a set shown by a function f_A where:

$$f_A : E \to P(U) \tag{2}$$

$$f_A(x) = 0 \quad if \quad x \notin A \tag{3}$$

f_A is approximate function of the soft set F_A, the value $f_A(x)$ is a set named x-element of the soft set for all $x \in E$. A soft set can be shown as:

$$F_A = \left\{ \left(x, f_A(x)\right) : x \in E, f_A(x) \in P(U) \right\} \tag{4}$$

For example, assume $U = \{u_1, u_2, u_3, u_4, u_5\}$ and $E = \{e_1, e_2, e_3, e_4\}$ be a set of attributes. If $A = \{e_1, e_2, e_4\} \subseteq E$, $f_A(e_1) = \{u_2, u_4\}$, $f_A(e_2) = U$ and $f_A(e_4) = \{u_1, u_3, u_5\}$ then the soft set F_A is:

$$F_A = \left\{ \left(e_1, \{u_2, u_4\}\right), \left(e_2, U\right), \left(e_4, \{u_1, u_3, u_5\}\right) \right\} \tag{5}$$

A fs-set Γ_A over U is a set shown as a function γ_A where:

$$\gamma_A : E \to F(U) \tag{6}$$

$$\gamma_A(x) = 0 \quad if \quad x \notin A \tag{7}$$

γ_A is fuzzy approximate function of the fs-set Γ_A and the value $\gamma_A(x)$ is a set named x-element of the fs-set for all $x \in E$. A fs-set Γ_A over U can be shown as:

$$\Gamma_A = \left\{ \left(x, \gamma_A(x)\right) : x \in E, \gamma_A(x) \in F(U) \right\} \tag{8}$$

So, for the above defined U, E, A;
$\gamma_A(e_1) = \left\{ \frac{0.9}{u_2}, \frac{0.5}{u_4} \right\}$, $\gamma_A(e_2) = U$ and $\gamma_A(e_4) = \left\{ \frac{0.2}{u_1}, \frac{0.4}{u_3}, \frac{0.8}{u_5} \right\}$ then
$F_A = \left\{ \left(e_1, \left\{ \frac{0.9}{u_2}, \frac{0.5}{u_4} \right\}\right), \left(e_2, U\right), \left(e_4, \left\{ \frac{0.2}{u_1}, \frac{0.4}{u_3}, \frac{0.8}{u_5} \right\}\right) \right\}$.

Now we want to define a fs-aggregation operator. A fs-aggregation function on the fuzzy sets is a combination of several approximate functions of an fs-set which make a single fuzzy set that is the aggregate fuzzy set of the fs-set. Let Γ_A be a fs-set over U, it can be presented as:

$$\begin{array}{c|cccc} \Gamma_A & e_1 & e_2 & \cdots & e_n \\ \hline u_1 & \mu_{\gamma_{A(e_1)}}(u_1) & \mu_{\gamma_{A(e_2)}}(u_1) & \cdots & \mu_{\gamma_{A(e_n)}}(u_1) \\ u_2 & \mu_{\gamma_{A(e_1)}}(u_2) & & & \\ \vdots & \vdots & \ddots & & \vdots \\ u_m & \mu_{\gamma_{A(e_1)}}(u_m) & \mu_{\gamma_{A(e_2)}}(u_m) & \cdots & \mu_{\gamma_{A(e_n)}}(u_m) \end{array} \tag{9}$$

Where $\mu_{\gamma_{A(x)}}$ is the membership function of γ_A. If $a_{ij} = \mu_{\gamma_{A(e_j)}}(u_i)$ then $\left[a_{ij}\right]_{m\times n} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix}$ is the matrix of the fs-set Γ_A over U. Then, the cardinal set of Γ_A denoted by $c\Gamma_A$ and defined by $c\Gamma_A = \left\{ \mu_{c\Gamma_A}(x)/x : x \in E \right\}$ is a fuzzy set over E. The membership function $\mu_{c\Gamma_A}$ of $c\Gamma_A$ is defined by $\mu_{c\Gamma_A} : E \to [0,1], \mu_{c\Gamma_A}(x) = \frac{|\gamma_A(x)|}{|U|}$ where $|U|$ is the cardinality of universe U and $|\gamma_A(x)|$ is the scalar cardinality of fuzzy set $\gamma_A(x)$, which is the sum of the membership values of all elements of the fuzzy set. Let Γ_A, $c\Gamma_A$ as defined before then fs-aggregation operator indicated by FS_{agg} is denoted by:

$$\mathrm{FS}_{agg} : cFS(U) \times FS(U) \to F(U) \tag{10}$$

$$\mathrm{FS}_{agg}(c\Gamma_A, \Gamma_A) = \Gamma_A^* \tag{11}$$

$$\Gamma_A^* = \left\{ \mu_{\Gamma_A^*}(u)/u : u \in U \right\} \tag{12}$$

The membership function $\mu_{\Gamma_A^*}$ of Γ_A^* is shown as $\mu_{\Gamma_A^*} : U \to [0,1]$, $\mu_{\Gamma_A^*}(u) = \frac{\sum_{e\in E} \mu_{c\Gamma_A}(e)\mu_{\gamma_{A(e)}}(u)}{|E|}$.

The suggested decision-making algorithm by Cagman et al. [114] is a four step method:

(1) Define a fs-set Γ_A over U.
(2) Calculate the cardinal set $c\Gamma_A$ of Γ_A.
(3) Denote the aggregation fuzzy set Γ_A^* of Γ_A.
(4) Denote the fittest alternative in this set which gives the highest membership grade by $\max \mu_{\Gamma_A^*}(u)$.

In other words, the fuzzy soft decision-making process works as follows:

1. Define the set of all alternatives as U.
2. Define the set of selected decision criteria as E.
3. Ask the decision maker/s to mark each attribute according to each criterion, marks should be a number between 0 and 1. The answers generate $\left[a_{ij}\right]_{m\times n} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix}$ matrix, rows show attributes and columns show criteria.
4. The sum of each column over the number of alternatives, gives us a $n \times 1$ matrix.
5. Multiply $\left[a_{ij}\right]_{m\times n}$ by the $n \times 1$ matrix of step 4. Divide each element by the number of alternatives. The result is final mark or grade of each alternative.
6. The alternative with maximum grade is the chosen alternative. We can sort alternatives by the grades also.

3. Research methodology

The aim of the current study is to recognize different forms of power in SC and choose the most appropriate form for the electronics manufacturing SC and each firm in mentioned SC. It is obvious that SC members are vulnerable as they depend on the other echelons for necessary material which are needed to obtain their goals, but the degree of vulnerability is not equal for all members. Due to this reliance deviation, resource dependence theory expects that the more impressive firm enacts its ability to serve its own advantages, to the impairment of the other firm. But the concept of SCM centers around the aggregate sum of power in a relationship, ignoring the distribution of it. Indeed, even within the sight of reliance asymmetry, joint reliance has been related with positive results for the two firms since they perceive the significance of collaborating to commonly achievements. According to the literature, power is anything but a unidimensional develop; there is the likelihood that various sorts of power might offset one another in a SC.

Some scholars believe that different forms of power exist simultaneously in SC configurations, it shows that potential power forms cause a beneficial impact, where initiated power forms are more manipulative and can have an unfavorable impact. Reviewing the literature on power, we found six power forms and designed a mixed decision-making process to find most appropriate power form for the studied SC. What makes this topic more complicated in case of SC, is the concept of total SC performance as the main goal of each SC members, so we decided to use SC performance measures as decision-making criteria. The list of measures obtained from literature which contained 21 SC performance measures. We used BWM to find the most important measures by the help of SCM experts from the electronics manufacturing SC.

The studied SC is active in assembly and manufacturing of various range of products in field of electrical locks and door phone systems in Iran. These products are the result of time-consuming research and design work, which are complicated and usually contain around 2000 pieces. The raw material and parts are designed and sometimes produced in different companies in different countries such as China, South Korea, Taiwan and Iran. Products are sold mostly in middle east countries such as Iran, Iraq, Syria, Pakistan, Afghanistan and also Russia, Armenia, Uzbekistan, Azerbaijan, etc. We chose this SC as an example of international and extensive SC. We tried to contact executive managers of different companies in this SC by the help of the commercial manager of the manufacturing company. We sent online questionnaires of BWM via Skype to 67 managers and could receive 34 filled questionnaires. Then using the solver, solved the main BWM mathematical model

$$\begin{aligned} &\min \epsilon \\ &s.t. \quad \sum_j w_j = 1,\ w_j \geq j; \quad for\ all\ j \\ &\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \epsilon \\ &\left|\frac{w_j}{w_w} - a_{jw}\right| \leq \epsilon \end{aligned} \tag{13}$$

and ranked the 21 founded SC performance measures.

Then considering six high rank SC performance measures as the result of this step, we started the second step. In second step, we applied a fuzzy soft set decision-making method, using the six SC performance measures as criteria to find best power form for the studied SC. In this level we sent new questionnaire to the same 34 experts who cooperated with us in previous step, this time we received 50 percent of questionnaires back which is 17 filled ones.

Then defined a fs-set over U, the set of all alternatives, which is all possible power forms. The cardinal set of this fs-set is calculated and give us the aggregate fuzzy set. Then as explained above, the highest membership grade distinguishes the fittest alternative for us which is the most appropriate power form considering SC performance measures. The results, calculations and analysis are reported in Section 4. To summarize and better explain the method, the main steps of this study are shown in Fig. 1.

4. Data analysis

Power, introduced in form of the potential to impress the decision and performance of others, is the foundation of SC configuration. As explained in Section 2.1, there are different power forms which blossoms from different potential characteristics or competencies of people/firms. Focusing on SC studies, imagine identity A may be happy of being a vendor to identity B, as a famous and rich company. The result is that A's strategies can be impressed by B, although B does not use/misuse or activate its power intentionally. So, power is a noetic concept, seen and felt by the influenced firm. In real world of business, where each echelon tries to achieve more benefits and success beside its efforts for SC success, it is critical to know if each firm has any power in accordance with other SC firms, and more than that it is crucial for SC members to know what kind of power is more practical for each player, that can help the whole SC to obtain more competitive position in their business. In this research we studied different kinds of power and constructed a process to choose the most applicable power form for companies of each level in the studied SC. Considering the main goal of SCM which is maximization of whole SC performance, we studied SC performance measures as the decision-making criteria. In Table 5 the ranking of all 21 measures, discovered from the literature, are shown. This result is calculated using BWM solver file which is a user friendly excel file [115]. Its instruction is as follows:

Step 1: Determine the number of decision criteria. This, of course, depends on your problem. If you have more than 9 criteria, it is recommended to first cluster the criteria into a number of clusters. Because the solver file, at least up to now, has different sheets for 3 to 9 criteria problem solvers.

This way, you add one level to the hierarchy of the problem, and solve the problem. To do the clustering you need to use theory and/or experts' opinion to make meaningful clusters.

We have 21 criteria so we divided them into 5 clusters with the help of experts. The clusters and dedicated criteria are shown in Table 4.

You can then use the Sheets C=4 and C=5 to do the analysis for the sub-sets respectively. You also need to do a pairwise comparison among the sub-sets using C=5 Sheet.

At the end you multiply the weight obtained for each criterion belong to each sub-set by the weight of the whole sub-set to get the "global" weight of the criteria. Note that the sum of the global weights of all the 21 criteria becomes 1.0.

Step 2: Determine the best (e.g., the most desirable, the most important) and the worst (e.g., the least desirable, the least important) criteria based on the opinion of the decision-maker.

As example we show calculations for cluster 2 (Relationship) by the opinion of first expert.

	The worst				The best
Criteria number = 5	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
Names of criteria	Collaboration with Stakeholders	Customer satisfaction	Delivery reliability	Human resources performance	Responsive-ness

Step 3&4: Express the preference of the decision-maker on "the Best criterion over all the other criteria", and the preference of "all the other criteria over the Worst" by selecting a number between 1 and 9 from the drop-box.

The meaning of the numbers 1–9:

1: Equal importance
2: Somewhat between Equal and Moderate
3: Moderately more important than
4: Somewhat between Moderate and Strong
5: Strongly more important than

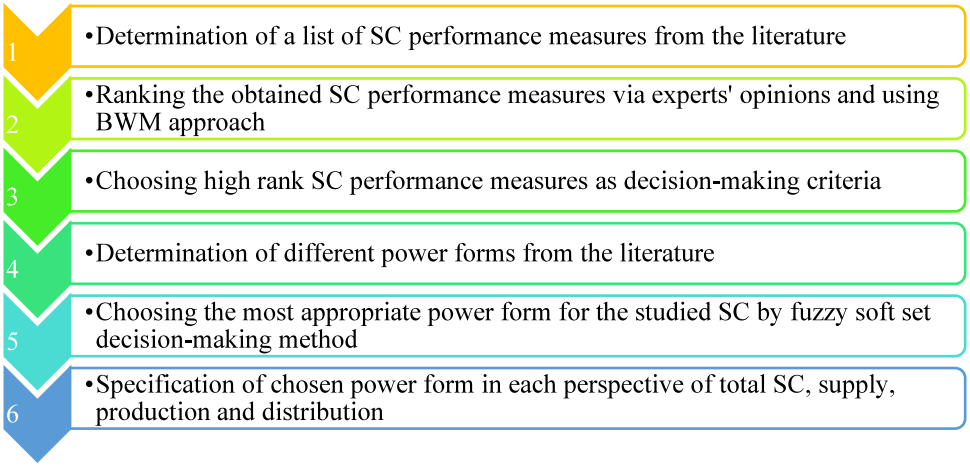

Fig. 1. Main steps of this study.

Table 4
Clusters of decision criteria.

Financial	Relationship	Internal affairs	External affairs	Product
Asset Management efficiency	Collaboration with stakeholders	Cycle efficiency	Environmental performance	Innovativeness
Cost of products	Customer satisfaction	Flexibility	Information security	Inventory levels
Cost of products	Delivery reliability	Internal process performance	Reliability	Lead time
Resources efficiency	Human resources performance	Productivity	Technological efficiency	Quality
	Responsiveness			

6: Somewhat between Strong and Very strong
7: Very strongly important than
8: Somewhat between Very strong and Absolute
9: Absolutely more important than

Best to others	Collaboration with stakeholders	Customer satisfaction	Delivery reliability	Human resources performance	Responsiveness
Responsiveness	4	3	7	9	1

Others to the worst	Collaboration with stakeholders	Customer satisfaction	Delivery reliability	Human resources performance	Responsive-ness
Collaboration with stakeholders	1	9	4	6	8

Step 5: Use Solver to solve the problem. By the data presented above the weights of criteria in cluster 2 are calculated:

Weights	Collaboration with stakeholders	Customer satisfaction	Delivery reliability	Human resources performance	Responsive-ness
	0.05762898	0.25356751	0.10867179	0.0845225	0.49560922

Following the above-mentioned instruction, we reached to the final results for all performance measures, presented in Table 5.

In Fig. 2 the weights of measures are more differentiable, as shown, the weights of first six criteria are more than 0.05 and has a significant difference from others so we choose these criteria as decision criteria to select appropriate power form in electronics manufacturing SC, which are "Financial Performance", "Resources Efficiency", "Customer Satisfaction", "Quality", "Asset Management Efficiency" and "Productivity".

We define the universal set of U to be a set of all power forms, $U = \{u_1, \ldots, u_6\}$ = {Coercion, Reward, Legitimate, Information, Expert, Reference} and E is the set of chosen criteria shown as $E = \{e_1, e_2, \ldots, e_6\}$ which stands for E = {Financial performance, Resources efficiency, Customer satisfaction, Quality, Asset management efficiency, Productivity} respectively.

The experts are asked to specify the membership degrees for each power form according to each chosen criteria from their point of view. For example, the result of first expert is as:

$$\Gamma_A = \left\{ \left(e_1, \left\{\frac{0.8}{u_2}, \frac{0.5}{u_4}, \frac{0.6}{u_5}, \frac{0.7}{u_6}\right\}\right), \left(e_2, \left\{\frac{0.3}{u_1}, \frac{0.8}{u_2}, \frac{0.6}{u_3}, \frac{0.7}{u_5}\right\}\right), \left(e_4, \left\{\frac{0.9}{u_1}, \frac{0.8}{u_2}, \frac{0.5}{u_3}, \frac{0.4}{u_4}, \frac{0.4}{u_5}\right\}\right), \left(e_5, \left\{\frac{0.7}{u_1}, \frac{0.7}{u_2}, \frac{0.3}{u_3}, \frac{0.5}{u_6}\right\}\right) \right\}$$

In step 2 the cardinal is computed:

$$c\Gamma_A = \left\{\frac{0.43}{e_1}, \frac{0.4}{e_2}, \frac{0.5}{e_4}, \frac{0.37}{e_5}\right\}$$

Then in step 3, the aggregate fuzzy set is calculated:

$$\mu_{\Gamma_A^*} = \frac{1}{6}\begin{bmatrix} 0 & 0.3 & 0 & 0.9 & 0.7 & 0 \\ 0.8 & 0.8 & 0 & 0.8 & 0.7 & 0 \\ 0 & 0.6 & 0 & 0.5 & 0.3 & 0 \\ 0.5 & 0 & 0 & 0.4 & 0 & 0 \\ 0.6 & 0.7 & 0 & 0.4 & 0 & 0 \\ 0.7 & 0 & 0 & 0 & 0.5 & 0 \end{bmatrix}\begin{bmatrix} 0.43 \\ 0.4 \\ 0 \\ 0.5 \\ 0.37 \\ 0 \end{bmatrix} = \begin{bmatrix} 0.1382 \\ 0.2205 \\ 0.1002 \\ 0.0692 \\ 0.123 \\ 0.081 \end{bmatrix}$$

Which means $\Gamma_A^* = \left\{\frac{0.1382}{u_1}, \frac{0.2205}{u_2}, \frac{0.1002}{u_3}, \frac{0.0692}{u_4}, \frac{0.123}{u_5}, \frac{0.081}{u_6}\right\}$, at the end in step 4, the maximum membership is identified for u_2 which means that the reward power is chosen by this expert. These calculations are formulated in Microsoft Excel worksheet. The same method is applied on all 17 experts' opinions and the final result is presented in Table 5.

Table 5
Supply chain performance measures ranking.

Measure	Main	Cluster	Total	Rank
Asset management efficiency	0.134565	0.523763	0.0705	5
Collaboration with stakeholders	0.156951	0.203686	0.0319	8
Cost of products	0.055409	0.523763	0.0290	9
Customer satisfaction	0.502242	0.203686	0.1023	3
Cycle efficiency	0.096899	0.101843	0.0098	17
Delivery reliability	0.089686	0.203686	0.0182	12
Environmental performance	0.05988	0.048497	0.0029	21
Financial performance	0.585752	0.523763	0.3067	1
Flexibility	0.213178	0.101843	0.0217	11
Human resources performance	0.041854	0.203686	0.0085	19
Information security	0.161677	0.048497	0.0078	20
Innovativeness	0.106383	0.122211	0.0130	15
Internal process performance	0.127907	0.101843	0.0130	14
Inventory levels	0.074468	0.122211	0.0091	18
Lead time	0.148936	0.122211	0.0182	13
Productivity	0.562016	0.101843	0.0572	6
Quality	0.670213	0.122211	0.0819	4
Reliability	0.562874	0.048497	0.0272	10
Resources efficiency	0.224274	0.523763	0.1174	2
Responsiveness	0.209268	0.203686	0.0426	7
Technological efficiency	0.215569	0.048497	0.0104	16

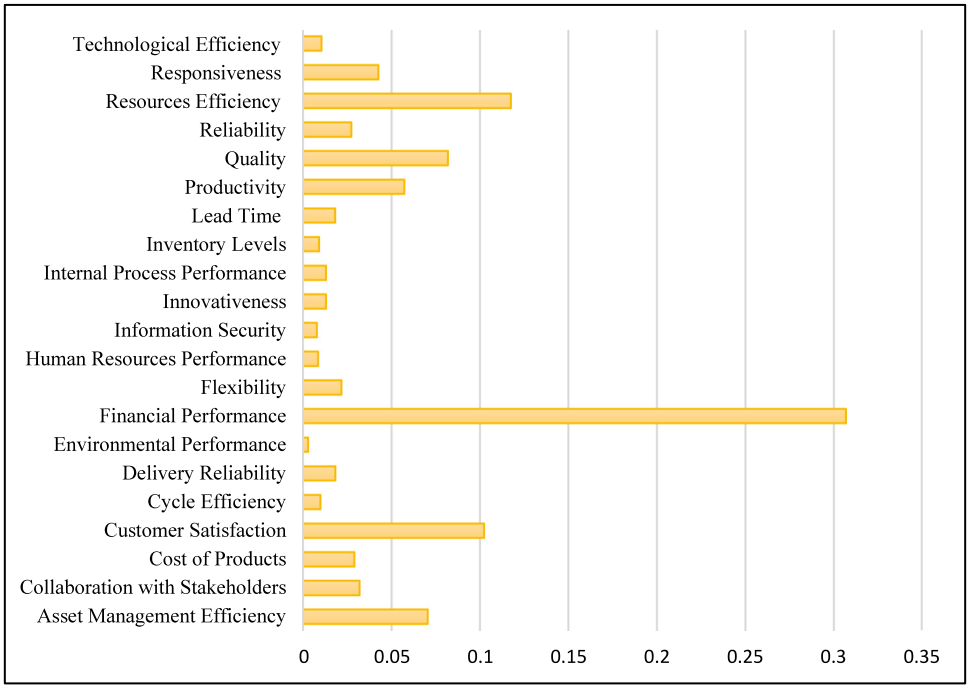

Fig. 2. Supply chain performance measures weights.

5. Sensitivity analysis

As the experts were chosen from different companied in SC, we also did the calculations separately for different clusters which were diagnosed according to the role of experts' specified companies in the studied SC, each person was asked to answer questions in two dimensions, upstream which means applying that power form toward upstream firms at supply side in their SC and downstream means use of that power form toward downstream firms at distribution and sale side of SC. The results are reported in Table 6. The selected power form in each perspective is shaded. The most appropriate power form for the studied electronics manufacturing SC, according to experts' opinions is "reward" although it is not the selected one for all levels specially supply companies.

The results show that the ranking of power forms in all perspective are not homogeneous, it is better shown in Fig. 3. Which means that a power form that can help a company to act well as a supplier in SC, may not help a company in role of distribution center.

6. Managerial implications

In Table 5, the differences between results of upstream and downstream dimension in each perspective, shows that each firm cannot choose the same approach toward all other firms in its SC, in other words because a company has different roles in its business, needs different power forms to succeed in each role. For example, a supplier in studied SC, who may choose to invest on referent power projects to achieve better performance toward its suppliers, need to focus on expert power toward its customers who are manufacturers of studied SC. Same according to the results it is suggested that companies with the role of production in the SC, try to achieve reward power toward their suppliers, it means they should try to act somehow that their

Table 6
Power form ranking in different perspectives.

	Power form	Ranks in perspectives of:						
		Total supply chain	Supply		Production		Distribution	
			upstream	downstream	upstream	downstream	upstream	downstream
u_1	Coercion	6	6	6	6	6	3	5
u_2	Reward	1	5	2	1	2	2	1
u_3	Legitimate	5	3	4	4	4	5	6
u_4	Information	4	2	5	3	5	1	4
u_5	Expert	2	4	1	5	1	4	2
u_6	Referent	3	1	3	2	3	6	3

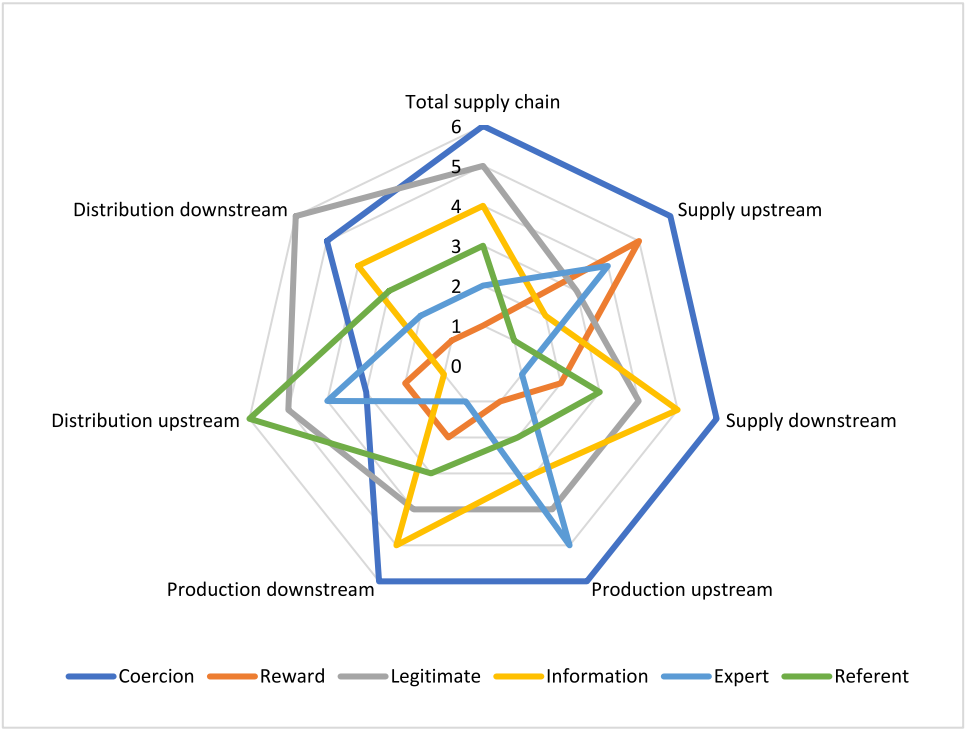

Fig. 3. Power form ranking in different perspectives.

suppliers feel they are getting some special option while working with this company, e.g. apply special payment options or in time/amount of orders apply some kind of behavior that can be called reward.

But toward their customers which can be distribution centers or wholesalers, expert power has got highest rank. Expert power is defined as attribution of mastery toward other company, it means in this SC manufacturers should have mastery in relation with distributors and customers, in other words such feeling can attract them more. It sounds logical in this industry because of the level of technology and knowledge in product design. It may change in consuming product SCs where the production process and system are not as complicated as the studied SC.

It is more interesting that the companies in distribution segment of this SC are not suggested to use same strategy toward their customers who can be retailers or final consumers. It seems that reward power can help them achieve more benefits and better performance. In other direction, these companies are suggested to use information power in relation with production sectors, it shows that in this SC manufacturers prefer to cooperate with companies who share market information with them and it is more important than any other factors for them. So, distribution companies who has better data center and customer relation management systems can have more power than other competitors.

It is surprising that "Coercion" and "Legitimate" power forms are not in first rank for any of perspectives which shows although the word "power" exerts a negative sense in general which is closest concept to coercion power, but is not selected by experts in any company. Legitimate power is also not selected by experts which might be a reason of time-consuming process when companies want to pursue some legal rights in conflicts. Applying a certain type of power in inter-organizational relationships requires the development of relevant strategies and is time-consuming and costly process, that is why it is so important for managers to choose the right form of power. For example, to achieve reward power over customers, a company should plan different promotion campaigns and more important is that they should find and implement different promotion packages which can be distinguished by customers so that they decide to fix their cooperation with them or change their cooperators and come to them for the rest of their business. It means if companies do not succeed in reaching to

that level of power they will easily, soon or late, loose their place in SCs.

Conclusions

The SCM concept basically focuses on rationality, objectivity, optimality, and controllability, but the main goal of this attitude is to achieve highest performance level as a whole. This approach brings a kind of cooperation and collaboration between firms in a SC but should not forget that each echelon is an independent identity and has its own strategies. It is also obvious that each firm should respond to its stakeholders so need to plan for its best performance as a firm as well as a SC member.

According to the viewpoint of the reliance distraught firm, consistence addresses loss of prudence, as it acquiesces to the desires of the other firm. To make up for this, rebuilding reliance through vulnerability decrease or looking for more steady admittance to assets is prescribed by academicians. Thus, it is assumed that power is purposefully actuated to influence other firms. It is logical that each firm does cost–benefit analysis for taking part in a relationship, seeing it as severable assuming its expenses offset the advantages. Results show that in a SC, upstream and downstream power might impact a firm in an unexpected way; along these lines, it is pivotal to think about power asymmetry as far as firm's role in SC as well as relationship direction.

Some practitioners believe that power asymmetry may stop firms' collaboration in SC but studies show that although one firm may hold a dependence advantage but the information that the relationship will proceed and acquire good performance level for whole SC, makes the organizations be more able to cooperate. Understanding the most appropriate power form is the initial step for a firm in accomplishing an upper hand inside a SC. It is related with long haul direction, compelling compromise and eagerness to forego quick personal responsibility to help the relationship. The following stage is improvement of procedures for obtaining that power position which is more advantageous. It brings about expanded degrees of joint activity, fine-grained data trade and trust.

Fine-grained data trade about client interest, sales forecasts, request status, stock levels, capacity constraints, lead times, quality and different points which can be assessed by performance measures listed in Table 2 is important to joint action. In this paper we proposed an algorithm to help managers find their best power form in their relations with other SC players. Although here we used performance measures as decision criteria which sounds logical and respondent experts also agreed but practitioners can use different set of criteria and choose most relevant among them and then easily find their most appropriate power form in accordance with those criteria, it can be considered as a new approach for new researches also. We provided the list of performance measures from literature but the differences between final calculated weights show that although all these measures were used in different researches but may not attract practitioners of all SCs or may not be same from their point of view while comparing them. That is why we decided not to use all of them and selected some which had higher ranks and weights. During the rest of process, we can see that although the experts of the same SC ranked the performance measures and helped to select decision criteria, but when coming to use them as criteria and mark power forms, again had different viewpoints while announcing membership degrees. These differences are more distinguishable in the final results where we see that experts at each firm looking at upstream or downstream of SC, although there are several firms in common, but has completely different viewpoints. For example, for an expert working in a company of distribution section, upstream means, wholesalers, manufacturers and suppliers and for an expert working in a company of production section, upstream means suppliers or other manufacturers, but the ranking of power forms is very exogeneous despite some common companies in the explained direction.

The proposed model is very user-friendly because it allows respondents to compare power forms by linguistic words which construct fuzzy numbers and are applied in the model, other forms of fuzzy numbers can be discussed and checked in future studies and new decision-making methods can be generated with that numbers or sets. Although power is a famous and familiar word in general but when we come to distinguish different forms of it and talk about differences they cause, many experts feel confused while are asked to mark them, that is why a fuzzy soft approach can be helping.

Strategic level decisions are vital for companies and same time they are usually costly and difficult decisions. Successful managers prefer to analyze such decisions from different viewpoints, the proposed algorithm help decision makers to consider as much criteria as they want and then in first step of model they can filter, rank and select among them. For managerial boards its crucial to know and make sure that any decision is 360 degrees analyzed.

The only limitation that authors faced in this study was difficulty of finding and convincing executive managers of the same SC to fill the questioners as they were in different geographical places and not all of them were good at English so sometimes, we needed to translate and explain some parts of questionnaire in local languages. We suggest other scholars to apply this model in other SCs and compare the results with ours to check the similarity and differences.

Declaration of competing interest

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

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