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SELECTING THE BEST SUPPLY CHAIN BY GOAL PROGRAMMING AND NETWORK DATA ENVELOPMENT ANALYSIS

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Abstract. Today, one of the most important problems of decision makers in most organizations is to choose the best supply chain. The main objective of this paper is to choose the best supply chain. To select the best supply chain this paper presents a model based on goal programming and network data envelopment analysis (NDEA). The proposed model enables decision makers to compare supply chains with predetermined goals. A case study is presented to validate the proposed model.

Keywords. Supply chain, network DEA, goal programming, data envelopment analysis.

Mathematics Subject Classification. 90C99.

1. Introduction

Supply chain is a series of interconnected organizations that are doing coordinated tasks and activities to produce and deliver the products or services to the customer. In each supply chain, coordination of the companies that produce goods or services is very essential. Supply chain is a set of organizations that are

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legally separated, but they are interrelated together in some aspects such as: flow of materials, information and finances. Generally, the supply chain includes all activities associated with the flow of goods and raw materials transformation till the final product delivery to the final consumer. Also the flow of financial resources and credits and the flow of information are two other flows which exist in supply chain. Supply chain management is integration of activities and information flows associated with supply chain. Also, supply chain management aims to achieve the best combination of responsiveness and efficiency to succeed in market. It should be mentioned that supply chain managers are always following reducing costs, faster delivery, increasing goods and services quality [19].

In today's organizations, one of the most important decisions is to choose the best supply chain. To select the best supply chain there are several techniques. One of the techniques in supply chain selection is fuzzy analytic network process (ANP) [27]. The other approach for selecting the best supply chain is network data envelopment analysis (NDEA) [13]. Data envelopment analysis (DEA) is a technique which calculates relative efficiency of decision making units (DMUs). Classical models of DEA deal with DMUs as black boxes. In other words, internal interactions of DMUs are ignored. This characteristic in some situations is appropriate. For example, if managers wish to evaluate the amount of inefficiency of DMUs or when they do not know the internal structure of DMUs, the black box approach is appropriate. However, this approach cannot identify internal interactions of DMUs to identify sources of inefficiency of DMUs [24].

In this paper, we provide ranking results using the model of Cook *et al.* [13]. Then, our new model and ranking method is provided. The purpose of running the Cook *et al.* [13] model is to compare the differences between the two methods.

The proposed slacks based NDEA model is based on constant returns to scale assumption which is considered as series network models. Moreover, in goal programming the goals are set for all supply chains. The goals are defined by manager for every input and output as benchmarks of both efficient and inefficient supply chains. Note that managers have a thorough knowledge from the facilities of each province (supply chain) On the basis of such knowledge the managers have specific expectations from future performance of each supply chain. Accordingly, they set goals for the supply chains. Stewart [34] did not set optimal difference between goals and current values (α) of inputs and outputs. In this paper, Shannon [31] entropy technique is used to determine optimal α. The contributions of this paper are as follows:

- For the first time, this paper incorporates goal programming into NDEA model.
- A case study is given to show the efficacy of the proposed model.
- A new ranking approach is proposed. In new ranking approach, rank of each DMU is obtained from the gap between current status of each DMU and goal of the DMU.
- Shannon entropy technique is used to calculate optimal α.

This paper is organized as follows. In Section 2 literature review is presented. Proposed model is given in Section 3. In Section 4 case study is presented. In Section 5 concluding remarks are presented.

2. Literature review

2.1. The uses of DEA in supply chain selection problems

DEA has been proposed for evaluating relative efficiency of DMUs [8]. Also, there have been wide usages of DEA in supply chain selection problems [18, 25]. Chen *et al.* [11] proposed a DEA game model to measure supply chain efficiency. Using multiple criteria in DEA, Yu *et al.* [39] proposed a model to estimate the efficiency of supply chains. However, they ignored to consider internal structures in their evaluation. In order to measure supply chain performance, Wong and Wong [38] introduced two DEA models including the technical efficiency model and cost efficiency model. Wong *et al.* [37] applied a simple method to measure supply chain efficiency in stochastic environment [36] studied the composition factors of supply chains during the invitation to auction and pricing. They selected the most suitable supply chain. Ketchen *et al.* [22] selected the best supply chain based on price factor. They introduced the price factor as a tool to create competitive advantages and better performance. Jinfeng *et al.* [20] proposed a decision model based on costing. In their method sourcing process for manufacturers is facilitated with information about sourcing partners cost and time of processing. Azadi *et al.* [2] introduced a chance-constraint DEA model for selecting the best suppliers in the presence of stochastic data and non-discretionary factors.

2.2. Benefits of NDEA in supply chain selection

Generally, most supply chains have complex network structures including several stages so that outputs of one stage become the inputs of another stage. Therefore, considering such internal stages in efficiency evaluation of supply chains (DMUs) is an important issue [15]. However, in classical models of DEA internal interactions are ignored. Consequently, we need to use the NDEA as a comprehensive tool to deal with internal interactions of supply chains. For the first time, Shephard and Färe [32] and Färe and Grosskopf [15, 16] introduced a DEA framework with multiple production stages to evaluate the efficiency of a DMU. Moreover, in recent years, many radial NDEA models have been proposed (e.g., [13, 17, 21, 24]).

Cook *et al.* [13] provided a NDEA model to select the best supply chains. Liang *et al.* [25] identified the efficiency of supply chains and its members using a nonlinear model. Using a radial network DEA model, Chen and Yan [12] proposed the NDEA models for measuring efficiency of supply chains.

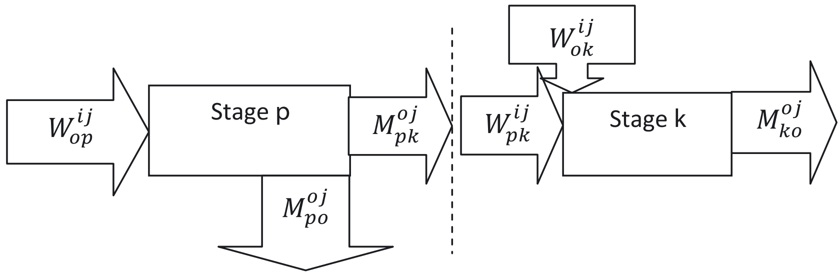

FIGURE 1. Typical network with series structure.

2.3. Goal Programming and DEA

Goal programming (GP) is a multi-objective programming technique for solving decision making problems. GP has been widely used for minimizing the deviations between the achievement of goals and desirable levels [5,28,29]. GP enables decision makers to minimize deviations from their expected goals [29]. For the first time, [7] developed GP. Then, GP was extended by Charnes and Cooper [6].

Using GP Sarkis and Talluri [30] introduced several factors to choose the best supply chains. Stewart [34] incorporated GP into DEA using Chebyshev function. He set goals for all inefficient and efficient DMUs to introduce benchmarks, but he did not take into account historical data. As a result, Stewart's approach was merely based on subjective judgment of managers. To reduce the interference of human factors, in this paper, we propose a mathematical technique (Shannon entropy technique). Then, using GP we incorporate manager's expectations into the NDEA model.

3. Proposed model

In this section, a new model is proposed. Figure 1 shows a typical network with series structure.

Here, following notations are defined. Subscript i shows entry factor and subscript o represents output factor. Subscript p indicates the previous stage and the subscript k represents next stage. This means that outputs of stage p enter the kth stage. The subscript s also shows the DMU under evaluation. Note that, in some cases there might be zero value. This means that either there is no previous stage or outputs which leave network as final product and do not enter next stages. We represent two kinds of output vectors M_{p0}^{oj} and M_{pk}^{oj}. The M_{p0}^{oj} is the output which leaves the network and is not entered as input to the next $(p+1)$ stage.

We also represent M_{pk}^{oj} as the output that enters the next stage as input.

W_{0k}^{ij}: the ith input $(i = 1, 2, \ldots, I)$ of jth DMU $(j = 1, \ldots, J)$ that enters the kth stage $(k = p + 1, \ldots, P + 1)$ from outside of the network.

W_{pk}^{ij}: the ith input ($i = 1, 2, \ldots, I$) of jth DMU ($j = 1, \ldots, J$) that exits from the stage p ($p = 1, \ldots, P$) and enters the kth stage as an input.

M_{p0}^{oj}: the oth output ($o = 1, 2, \ldots, O$) of jth DMU ($j = 1, \ldots, J$) that exits from pth stage ($p = 1, \ldots, P$) as final product and leaves the network.

M_{pk}^{oj}: the oth output ($o = 1, 2, \ldots, O$) of jth DMU ($j = 1, \ldots, J$) that exit from the pth stage ($p = 1, \ldots, P$) and enters the kth stage. These sorts of outputs are considered as input in the next stage but they are as output of the stage under evaluation.

$\eta_{\mathrm{J}} \geqslant 0$ is benchmark for inefficient DMUs.

$\sum_{j=1}^{J} \eta_j W_{0k}^{ij}$: is sum of inputs which enter from outside of the network ($i = 1, 2, \ldots, I$).

$\sum_{j=1}^{J} \eta_j M_{pk}^{oj}$: is sum of outputs which exit from stage and enter as inputs into other stages ($o = 1, 2, \ldots, O$).

$\sum_{j=1}^{J} \eta_j W_{pk}^{ij}$: is sum of inputs which exit from stage and enter as inputs into the next stages ($i = 1, 2, \ldots, I$).

$\sum_{j=1}^{J} \eta_j M_{p0}^{oj}$: is sum of outputs which exit from stage and exit as outputs of the network ($o = 1, 2, \ldots, O$).

g_{ij}^{I}: is the goal related to ith input. It is determined by manager and acts as benchmark for all networks ($i = 1, 2, \ldots, I$).

h_{oj}^{O}: is the goal related to oth output ($o = 1, 2, \ldots, O$).

In our model some stages have outputs which are considered as inputs in next stages. It should be noted that these factors are defined from two aspects; M_{pk}^{oj} is defined from the output aspect and W_{pk}^{ij} is defined from the input aspect. Since these factors are considered as outputs, we maximize them in the process of goal setting. On the other hand, these factors are also considered as inputs for the next stages, which we minimize Since achieving goals are not guaranteed, a deviational variable is defined for all the input and output goals. δ_{ij}^{i} and δ_{oj}^{O} are defined as deviational variables of the goals of inputs and outputs, respectively. We wish to minimize the deviational variables. Therefore, hyperplanes are determined by goals, which ideally their deviational variables equal to zero. When amounts of deviational variables are increased, the hyperplanes move toward each other and reach to joint point. As a result, they make feasible region.

The expressions associated with goals for network's inputs and outputs are defined as follows:

$W_{0k}^{Is*} - \delta_{is}^{I} \leqslant g_{is}^{I}$ ($i = 1, 2, \ldots, I$) are the inputs which enter the stage from outside.

$W_{pk}^{Is*} - \delta_{is}^{I} \leqslant g_{is}^{I}$ ($i = 1, 2, \ldots, I$) are the inputs which enter the stage under evaluation as an output of previous stage.

$M_{pk}^{Os*} + \delta_{os}^{O} \geqslant h_{os}^{O}$ ($o = 1, \ldots, O$) are the outputs which exit from stage and enter the next stage as inputs.

$M_{p0}^{Os*} + \delta_{os}^{O} \geqslant h_{os}^{O}$ ($o = 1, \ldots, O$) are the outputs which exit the stage and do not enter the next stage. In other words, they exit from network.

$W_{0k}^{is} - g_{is}^{I}$ is the difference between current value of input and its goal. If the goal is less than current usage of input, the difference is positive. If they are equal, the difference is zero.

$h_{os}^{O} - M_{pk}^{os}$ is the difference between the output's goal and current value of output. If the goal is more than current value of output, the difference is positive. If the goal is equal to the current value of output, the difference is zero.

As mentioned earlier, Stewart [34] determined α arbitrarily. In this paper, in order to reduce subjective judgment of decision maker in determining α, we propose Shannon's entropy technique [31]. The α indicates the importance of each factor which can be set by decision makers. The α is result of subtracting the current values of each supply chain from the goals of the same supply chain and it is between 0 and 1. The deduction is based on pairwise comparisons of the inputs/outputs of each supply chain. Moreover, the obtainedα indicates the importance of each factor. In other words, a supply chain which has minimum gap between its current values and its goals obtains a larger value of the α. Also, if the obtained α values for the factors are not approved by managers, they can adjust them and incorporate their expectations into the obtainedα values.

Note that this amount is between $0 \leqslant \propto \leqslant 1$ which decision maker determines as importance of the difference. The $\propto = 0$ means lowest importance for the difference, and $\propto = 1$ means high importance of the difference. The constraints related to the input's goals are defined as follows:

$$\sum_{j=1}^{J} \eta_j W_{0k}^{ij} - \delta_{is}^{I} \leqslant W_{0k}^{is} - \alpha(W_{0k}^{is} - g_{is}^{I}) \quad (i = 1, 2, \ldots, I),$$

$$\sum_{j=1}^{J} \eta_j W_{pk}^{ij} - \delta_{is}^{I} \leqslant W_{pk}^{is} - \alpha(W_{pk}^{is} - g_{is}^{I}) \quad (i = 1, 2, \ldots, I). \tag{3.1}$$

The constraints related to the output's goals are defined as follows:

$$\sum_{j=1}^{J} \eta_j M_{pk}^{oj} + \delta_{os}^{O} \geqslant M_{pk}^{os} + \alpha(h_{os}^{O} - M_{pk}^{os}), \quad (o = 1, \ldots, O),$$

$$\sum_{j=1}^{J} \eta_j M_{p0}^{oj} + \delta_{os}^{O} \geqslant M_{p0}^{os} + \alpha(h_{os}^{O} - M_{p0}^{os}), \quad (o = 1, \ldots, O). \tag{3.2}$$

We represent two kinds of variables v_{is}^{I} and v_{os}^{O} as weight of goals, where Δ, δ_{is}^{I} $(i = 1, \ldots, I)$ and δ_{os}^{O} $(o = 1, \ldots, O)$ are unconstrained in sign. Using ε we can minimize deviational variables from goals. If these deviational variables become less, it means we are getting closer to the goals. The ε is an arbitrarily small and positive value. Here, we use Chebychev scalarizing function for the goals as follows:

$$\max\left\{\max_{i=1} v_{is}^{I}\delta_{is}^{I} \ \max_{o=1}; v_{os}^{O}\delta_{os}^{O}\right\} + \varepsilon\left[\sum_{i=1}^{I} v_{is}^{I}\delta_{is}^{I} + \sum_{o=1}^{O} v_{os}^{O}\delta_{os}^{O}\right]. \tag{3.3}$$

Using this function we ensure that the solution is efficient in the feasible solutions and also it is on the efficient frontier of production possibility set (PPS) [34]. The weights enable to assign different priorities to the goals. Since these goals may have similar importance, we can assign equal weights. By this hyperplane, we can specify appropriate point.

Now, the final proposed model is defined as follows:

$$\min\ \Delta + \varepsilon \left[\sum_{i=1}^{I} v_{is}^{I} \delta_{is}^{I} + \sum_{o=1}^{O} v_{os}^{O} \delta_{os}^{O} \right],$$

s.t

$$\begin{aligned}
&\sum_{j=1}^{J} \eta_j W_{0k}^{ij} - \delta_{is}^{i} \leqslant W_{0k}^{is} - \alpha(W_{0k}^{is} - g_{is}^{i}) \quad (i = 12, \dots, I),\\
&\sum_{j=1}^{J} \eta_j W_{pk}^{ij} - \delta_{is}^{i} \leqslant W_{pk}^{is} - \alpha(W_{pk}^{is} - g_{is}^{i}) \quad (i = 1, 2, \dots, I),\\
&\sum_{j=1}^{J} \eta_j M_{pk}^{oj} + \delta_{os}^{O} \geqslant M_{pk}^{os} + \alpha(h_{os}^{O} - M_{pk}^{os}) \quad (o = 1, 2, \dots, O),\\
&\sum_{j=1}^{J} \eta_j M_{p0}^{oj} + \delta_{os}^{O} \geqslant M_{p0}^{os} + \alpha(h_{os}^{O} - M_{p0}^{os}) \quad (o = 1, 2, \dots, O),\\
&\Delta - v_{is}^{i} \delta_{is}^{i} \geqslant 0,\\
&\Delta - v_{os}^{O} \delta_{os}^{O} \geqslant 0,\\
&\eta_j \geqslant 0 \qquad (j = 1, 2, \dots, J).
\end{aligned} \tag{3.4}$$

4. Case study

Hamayesh−Afarinan is an Iranian, public, and not for profit organization which holds seminars. This company enjoys more than 20 years of experience in holding national and international seminars and conferences. Here, we focus on national non-profit conferences of Iranian inventions. These conferences are hold annually to identify talents. In 2013, conferences were held in 12 Iranian provinces. In this paper we define 12 provinces as 12 supply chains. In other words, we suppose each province is a supply chain and compare it with other supply chains (provinces). Every conference has four stages. In the first stage, two inputs including service staff and host staff are entered. In this stage, all required space and locations are furnished and are made ready for guests. This stage has an output entitled partly-prepared halls and booths which exits from the first stage and enters directly into the second stage. Stage 2 has two inputs. The first input is partly-prepared halls and booths which comes from previous stage and the second input is number of hosts that comes from outside of the network (supply chain). In this stage fully-prepared halls and booths is the only output which exits this stage and enters to the third stage. Stage 3 has two inputs including fully-prepared halls and booths

TABLE 1. The Cardinal scale for converting the qualitative output into quantitative values.

Values	Scale
33−40	High
25−32	Good
17−24	Medium
9−16	Weak
1−8	Very weak

and experts for holding the conference as external input. Also, stage 3 has two sorts of outputs. The first output is the extra consultation services (man-hour) which exits stage 3 but does not enter to the next stage. Note that, since the conference is non-profit, there are no incomes in the supply chains. In stage 3, experts enter to the supply chain for providing consultation services to the guests who will enter in the fourth stage. Also, experts in the third stage give consultation services to some of regional authorities who are associated with the conference indirectly and they do not attend at the conference professionally. In other words, the experts will introduce some new opportunities related to commercializing inventions to regional authorities.

The second output of the stage 3 is readiness of all staffs for holding the conference that enters the next stage. Finally, stage 4 is the operational phase in which the conference is held. This stage has two inputs. The first one is readiness of all staffs and the second one number of guests and inventors as an external input. Stage 4 has three outputs including satisfaction of guests and inventors, encouraging inventors, and introducing practical inventions to industry and market. These three outputs are considered as final outputs which exit from the supply chain.

The outputs "encouraging inventors", and "introducing practical inventions to industry and market" are quantitative factors. The encouraging inventors implies to number of inventors' projects that are encouraged and supported. Moreover, the introducing practical inventions to industry and market implies the number of signed contracts by inventors and manufacturers for commercializing their inventions. However, "satisfaction of guests and inventors" is a qualitative output. This qualitative output, using a scale of 1 to 40, is transformed to a cardinal scale by inventors and guests. Then the average of opinions is calculated. In Table 1, using cardinal scale, the qualitative output is transformed into quantitative values.

Figure 2 shows structure of this supply chain.

The data set, inputs, and outputs of differentstages of supply chains (DMUs) are presented in Table 2.

To evaluate supply chains we use Cook *et al.* [13] model. Calculations related to these 12 supply chains (DMUs) are done by Lingo software which the results are given in Table 3.

As is seen, supply chain #5 has the highest efficiency score of 1. Now, decision maker sets goals for each supply chain. A supply chain which has smallest difference with its goals is better supply chain.

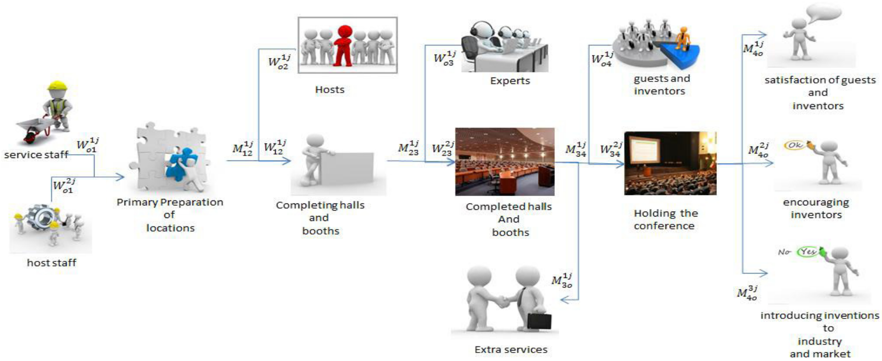

FIGURE 2. Supply chain of national conference of Iranian inventions.

TABLE 2. The inputs and outputs of different stages of supply chains.

Supply chains (DMUs)	Primary preparation of locations			Completing halls and booths		Completed halls and booths			Holding the conference			
	Service staff	Host staff	Partly-prepared halls and booths	Hosts	Fully-prepared halls and booths	Experts	Extra services	Readiness for holding conference	Guests and inventors	Satisfaction of guests and inventors	Encouraging inventors	Introducing inventions to industry and market
	w_{01}^{1j}	w_{01}^{2j}	$M_{12}^{1j} = w_{12}^{1j}$	w_{02}^{1j}	$M_{23}^{1j} = w_{23}^{2j}$	w_{03}^{1j}	M_{30}^{1j}	$M_{34}^{1j} = w_{34}^{2j}$	w_{04}^{1j}	M_{40}^{1j}	M_{40}^{2j}	M_{40}^{3j}
1	15	31	38	32	51	57	30	43	67	25	17	45
2	18	43	32	36	39	48	20	26	73	21	18	31
3	8	51	30	48	29	61	34	19	78	22	37	50
4	13	37	22	41	31	44	19	27	66	30	36	50
5	10	29	34	41	68	50	40	58	70	23	41	69
6	21	37	33	45	39	55	43	24	77	18	21	56
7	18	29	32	44	51	49	39	20	81	19	31	60
8	13	39	28	58	42	70	55	29	69	23	14	40
9	20	48	35	55	49	56	40	29	73	21	19	50
10	14	50	51	74	62	49	31	42	58	14	20	45
11	18	61	58	49	43	22	20	29	87	11	27	35
12	12	44	36	41	52	49	60	12	78	20	31	40

Table 3. The results.

Supply chains (DMUs)	Efficiency scores	Rank
1	0.928	3
2	0.985	2
3	0.725	10
4	0.878	4
5	1	1
6	0.85	5
7	0.795	9
8	0.645	12
9	0.7	11
10	0.8	8
11	0.84	6
12	0.82	7

Table 4 indicates the goals for DMUs. As Table 4 depicts each row shows the goals for inputs/outputs of each DMU. These goals are set by decision maker. It should be noted that we have some outputs which become inputs for next stage. In this case decision maker minimizes the goals from input aspect and also maximizes the goals from output aspect. These goals are set for 2014. Notice that decision maker expectation from the supply chain #5 is higher than other supply chains as supply chain #5 is located in a big province which enjoys strong infrastructures.

Stewart [34] determined the α arbitrarily. In this paper, we use Shannon entropy technique to determine α [31]. The calculated α is confirmed by managers. Note that if the calculated α is not accepted by managers, they can adjust the weights.

Table 5 shows α values resulting from difference between goals and current values of inputs and outputs. We deduct current inputs from input's goals and deduct output's goals from current outputs.

At this juncture, to determine α, Shannon entropy calculations are given. In Table 6, we normalize the data set in Table 5 by $p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}$ formula, where r_{ij} is element of ith row $(i = 1, 2, \ldots, m)$ and jth column $(j = 1, 2 \ldots, n)$. p_{ij} is normalized element of ith row $(i = 1, 2, \ldots, m)$ and jth column $(j = 1, 2, \ldots, n)$ in Table 5.

Now, we calculate amounts of these differences by (5). In other words we calculate amounts of differences between current inputs and outputs of supply chains and their associated goals. If the goal is less than current input, the difference is positive. If they are equal, the difference is zero. We also calculate the difference between the output's goal and current output. If the goal is more than current output, the difference is positive. If the goal is equal to current output, the difference is zero. The results are presented in Table 7.

$$K = \frac{1}{\ln m},$$

$$\propto = -K \sum_{i=1}^{m} (p_{ij} . \ln p_{ij}), \qquad (i = 1, 2, \ldots, m). \tag{4.1}$$

TABLE 4. Supply chain goals.

Supply chains (DMUs)	Primary preparation of locations			Completing halls and booths			Completed halls and booths				Holding the conference				
	Service staff	Host staff	Partly-prepared halls and booths	Partly-prepared halls and booths	Hosts	Fully-prepared halls and booths	Fully-prepared halls and booths	Experts	Extra services	Readiness for holding the conference	Readiness for holding the conference	Guests and inventors	Satisfaction of guests and inventors	Encouraging inventors	Introducing inventions to industry and market
	w_{01}^{1j}	w_{01}^{2j}	M_{12}^{1j}	w_{12}^{1j}	w_{02}^{1j}	M_{23}^{1j}	w_{23}^{2j}	w_{03}^{1j}	M_{30}^{1j}	M_{34}^{1j}	w_{34}^{2j}	w_{04}^{1j}	M_{40}^{1j}	M_{40}^{2j}	M_{40}^{3j}
1	8	29	39	35	30	67	49	40	30	47	40	53	29	36	59
2	15	37	49	28	28	69	38	30	41	48	22	50	22	30	45
3	8	45	34	28	42	31	26	57	42	23	17	70	25	42	75
4	12	29	30	17	40	70	30	38	50	63	26	50	32	49	55
5	8	27	35	32	30	69	65	30	70	79	50	43	28	49	90
6	18	33	48	25	40	88	35	43	40	60	19	50	31	22	67
7	12	27	39	27	35	74	51	35	46	59	17	69	34	40	75
8	10	20	30	27	41	71	36	30	60	40	28	53	30	24	43
9	12	28	41	26	49	78	49	40	50	88	29	35	29	27	55
10	14	30	83	37	60	75	59	30	41	42	38	49	23	24	55
11	15	48	60	57	40	93	39	18	30	57	25	71	24	39	40
12	7	35	44	30	30	74	50	35	62	40	12	60	30	45	43

The last row of Table 7 is the used α in the Model (4). Now, results of supply chains #5 and #3 are described in Tables 8 and 9, respectively[4]. Here, using the Model (4) supply chains are ranked. This ranking shows the comparison between current inputs/outputs of supply chains and their defined goals. As is seen in Table 8, "current performance" row indicates current amounts of input and output of supply chain #5. "Goals" row shows goals of inputs and outputs determined by decision maker. The "α" row is obtained from Table 7 to be included into the Model (4). The "goal-based benchmarks for various α" row represents the result of running the Model (4) using α. The "gap" row shows the difference between "goal-based benchmarks" for various α and current performance. The "weighted gap" row is obtained from multiplying the "gap" row by α. The "sum of weighted gap" is the final score obtained for supply chain. As is seen, "sum of

[4] For the sake of brevity, we have discussed only two supply chains. Similar discussions can be repeated for other supply chains.

TABLE 5. Differences between goals and current inputs and outputs (α).

Supply chains (DMUs)	Primary preparation of locations			Completing halls and booths			Completed halls and booths				Holding the conference				
	Service staff	Host staff	Partly-prepared halls and booths	Partly-prepared halls and booths	Hosts	Fully-prepared halls and booths	Fully-prepared halls and booths	Experts	Extra services	Readiness for holding the conference	Readiness for holding the conference	Guests and inventors	Satisfaction of guests and inventors	Encouraging inventors	Introducing inventions to industry and market
	w_{01}^{1j}	w_{01}^{2j}	M_{12}^{1j}	w_{12}^{1j}	w_{02}^{1j}	M_{23}^{1j}	w_{23}^{2j}	w_{03}^{1j}	M_{30}^{1j}	M_{34}^{1j}	w_{34}^{2j}	w_{04}^{1j}	M_{40}^{1j}	M_{40}^{2j}	M_{40}^{3j}
1	7	2	1	3	2	16	2	17	0	4	3	14	4	19	14
2	3	6	17	4	8	30	1	18	21	22	4	23	1	12	14
3	0	6	4	2	6	2	3	4	8	4	2	8	3	5	25
4	1	8	8	5	1	39	1	6	31	36	1	16	2	13	5
5	2	2	1	2	11	1	3	20	30	21	8	27	5	18	21
6	3	4	14	8	5	49	4	12	3	36	5	27	13	1	11
7	6	2	6	5	9	23	0	14	1	39	3	12	11	9	15
8	3	19	2	1	17	29	6	40	5	11	1	16	6	10	3
9	8	20	13	9	6	29	0	16	10	59	0	38	2	8	5
10	0	20	24	14	34	13	3	19	10	0	4	9	10	4	10
11	3	13	2	1	19	50	4	4	10	28	4	16	13	12	5
12	5	9	8	6	11	22	2	14	2	28	0	18	10	14	3
$\sum_{i=1}^{m} r_{ij}$	41	111	100	60	99	303	29	184	131	288	35	224	80	125	131

weighted gap" for supply chain #5 is −188.245. It means it has a big difference with goals. In Table 3, supply chain #5 was introduced as unique efficient DMU. However, it has considerable distance with goals.

Table 9 depicts the results of analysis for supply chain #3. In Table 9, sum of weighted gaps for the supply chain #3 is −66.297. As is seen, sum of weighted gaps for supply chain #3 is less than sum of weighted gaps for supply chain #5.

Table 10 shows summary of results using our proposed approach. The ranking is done on the basis of sum of weighted gaps. Since supply chain #3 has minimum sum of weighted gaps with its goals, as Table 10 addresses, it is the best supply chain. Although, supply chain #5 was introduced as unique efficient DMU in Table 3, here due to considerable distance with its goals, it obtains the rank 12.

TABLE 6. Normalized differences between goals and current inputs and outputs (α).

Supply chains (DMUs)	Primary preparation of locations			Completing halls and booths			Completed halls and booths				Holding the conference				
	Service staff	Host staff	Partly-prepared halls and booths	Partly-prepared halls and booths	Hosts	Fully-prepared halls and booths	Fully-prepared halls and booths	Experts	Extra services	Readiness for holding the conference	Readiness for holding the conference	Guests and inventors	Satisfaction of guests and inventors	Encouraging inventors	Introducing inventions to industry and market
	w_{01}^{1j}	w_{01}^{2j}	M_{12}^{1j}	w_{12}^{1j}	w_{02}^{1j}	M_{23}^{1j}	w_{23}^{2j}	w_{03}^{1j}	M_{30}^{1j}	M_{34}^{1j}	w_{34}^{2j}	w_{04}^{1j}	M_{40}^{1j}	M_{40}^{2j}	M_{40}^{3j}
1	0.17	0.02	0.01	0.05	0.03	0.05	0.069	0.09	0	0.01	0.086	0.06	0.05	0.125	0.11
2	0.07	0.05	0.17	0.068	0.06	0.1	0.034	0.1	0.16	0.08	0.114	0.1	0.0125	0.096	0.11
3	0	0.05	0.04	0.034	0.05	0.01	0.103	0.02	0.05	0.01	0.057	0.04	0.0375	0.04	0.19
4	0.02	0.07	0.08	0.084	0.01	0.13	0.034	0.03	0.24	0.125	0.029	0.07	0.025	0.104	0.04
5	0.05	0.02	0.01	0.034	0.07	0.003	0.103	0.11	0.23	0.07	0.228	0.12	0.0625	0.144	0.16
6	0.07	0.04	0.14	0.13	0.04	0.16	0.138	0.06	0.02	0.125	0.143	0.12	0.1625	0.008	0.08
7	0.15	0.02	0.06	0.084	0.07	0.08	0	0.08	0.01	0.13	0.086	0.05	0.1375	0.072	0.11
8	0.07	0.17	0.02	0.018	0.13	0.1	0.208	0.22	0.04	0.04	0.029	0.07	0.075	0.08	0.02
9	0.2	0.18	0.13	0.15	0.05	0.1	0	0.09	0.08	0.2	0	0.17	0.025	0.064	0.04
10	0	0.18	0.24	0.23	0.26	0.04	0.103	0.1	0.08	0	0.114	0.04	0.125	0.032	0.08
11	0.07	0.12	0.02	0.018	0.15	0.165	0.139	0.02	0.08	0.105	0.114	0.07	0.1625	0.096	0.04
12	0.13	0.08	0.08	0.1	0.08	0.062	0.069	0.08	0.01	0.105	0	0.09	0.125	0.112	0.02

5. CONCLUDING REMARKS

Supply chain management aims to maximize customer satisfaction. Supply chain managers can increase customer satisfaction by reducing costs and raising quality of goods and services. To achieve such an advantage selecting the best supply chain is an important task for supply chain managers. To this end supply chain managers not only should reduce costs and increase goods and services' quality, but also they should pay enough attention to faster delivery and coordination of whole supply chain from raw materials stage until delivery to final customers [19].

Generally, the main advantage of our new approach is to incorporate managers' expectations and goals in assessing supply chains while previous NDEA models did not take into account these important issues. In this paper we proposed a new method for ranking supply chains based on goals of decision maker. To this end, we defined new goals as benchmarks for all efficient and inefficient supply chains. Then, a new ranking method based on the gap between current values of each supply chain and its goals were proposed. We used Shannon entropy technique to

TABLE 7. Amounts of differences.

	Primary preparation of locations			Completing halls and booths			Completed halls and booths				Holding the conference				
	Service staff	Host staff	Partly-prepared halls and booths	Partly-prepared halls and booths	Hosts	Fully-prepared halls and booths	Fully-prepared halls and booths	Experts	Extra services	Readiness for holding the Conference	Readiness for holding the Conference	Guests and inventors	Satisfaction of guests and inventors	Encouraging inventors	Introducing inventions to industry and market
	w_{01}^{1j}	w_{01}^{2j}	M_{12}^{1j}	w_{12}^{1j}	w_{02}^{1j}	M_{23}^{1j}	w_{23}^{2j}	w_{03}^{1j}	M_{30}^{1j}	M_{34}^{1j}	w_{34}^{2j}	w_{04}^{1j}	M_{40}^{1j}	M_{40}^{2j}	M_{40}^{3j}
$\propto$	0.894	0.862	0.858	0.901	0.894	0.909	0.874	0.926	0.816	0.88	0.863	0.962	0.91	0.93	0.918

TABLE 8. The results of supply chain #5.

	Primary preparation of locations			Completing halls and booths			Completed halls and booths				Holding the conference					
	Service staff	Host staff	Partly-prepared halls and booths	Partly-prepared halls and booths	Hosts	Fully-prepared halls and booths	Fully-prepared halls and booths	Experts	Extra services	Readiness for holding the Conference	Readiness for holding the Conference	Guests and inventors	Satisfaction of guests and inventors	Encouraging inventors	Introducing inventions to industry and market	
	w_{01}^{1j}	w_{01}^{2j}	M_{12}^{1j}	w_{12}^{1j}	w_{02}^{1j}	M_{23}^{1j}	w_{23}^{2j}	w_{03}^{1j}	M_{30}^{1j}	M_{34}^{1j}	w_{34}^{2j}	w_{04}^{1j}	M_{40}^{1j}	M_{40}^{2j}	M_{40}^{3j}	
Current performance	10	29	34	34	41	68	68	50	40	58	58	70	23	41	69	
Goals	8	27	35	32	30	69	65	30	70	79	50	43	28	59	90	
$\propto$	0.894	0.862	0.858	0.901	0.894	0.909	0.874	0.926	0.816	0.88	0.863	0.962	0.91	0.93	0.918	
Goal-based benchmarks for various $\propto$	7.47	23.74	36.12	29.614	25.88	73.589	59.228	25.1	64.387	81.401	48.55	37.4	28.375	61.506	93.387	
Gap	−2.53	−5.26	−2.12	−4.386	−15.12	−5.589	−8.772	−24.9	−24.387	−23.401	−9.45	−32.6	−5.375	−20.506	−24.387	Sum of weighted gaps
Weighted gap	−2.262	−4.534	−1.819	−3.952	−13.52	−5.08	−7.667	−23.06	−19.9	−20.593	−8.15	−31.361	−4.89	−19.07	−22.387	−188.245

TABLE 9. The results of supply chain #3.

	Primary preparation of locations			Completing halls and booths			Completed halls and booths				Holding the conference					
	Service staff	Host staff	Partly-prepared halls and booths	Partly-prepared halls and booths	Hosts	Fully-prepared halls and booths	Fully-prepared halls and booths	Experts	Extra services	Readiness for holding the Conference	Readiness for holding the Conference	Guests and inventors	Satisfaction of guests and inventors	Encouraging inventors	Introducing inventions to industry and market	
	w_{01}^{1j}	w_{01}^{2j}	M_{12}^{1j}	w_{12}^{1j}	w_{02}^{1j}	M_{23}^{1j}	w_{23}^{2j}	w_{03}^{1j}	M_{30}^{1j}	M_{34}^{1j}	w_{34}^{2j}	w_{04}^{1j}	M_{40}^{1j}	M_{40}^{2j}	M_{40}^{3j}	
Current Performance	8	51	30	30	48	29	29	61	34	19	19	78	22	37	50	
Goals	8	45	34	28	42	31	26	57	42	23	17	70	25	42	75	
$\propto$	0.894	0.862	0.858	0.901	0.894	0.909	0.874	0.926	0.816	0.88	0.863	0.962	0.91	0.93	0.918	
Goal-based benchmarks for various $\propto$:	8	46.38	32.175	26.568	42.636	30.818	26.378	57.296	40.528	22.52	17.247	70.304	24.73	41.65	72.95	
Gap	0	−4.62	−2.175	−3.432	−5.364	−1.818	−2.622	−3.704	−6.528	−3.52	−1.753	−7.696	−2.73	−4.65	−22.95	Sum of weighted gaps
Weighted gap	0	−3.982	−1.866	−3.092	−4.795	−1.652	−2.292	−3.43	−5.327	−3.1	−1.513	−7.403	−2.484	−4.324	−21.068	−66.297

TABLE 10. The results using our proposed approach.

Supply chains (DMUs)	Sum of weighted gaps	Rank
1	−92.4	7
2	−87.027	6
3	−66.297	1
4	−68.349	2
5	−188.245	12
6	−117.318	8
7	−79.218	5
8	−134.406	9
9	−72.942	4
10	−69.402	3
11	−145.369	10
12	−147.853	11

weigh the gaps and defined appropriate α which is between 0 and 1. As a result, we removed subjective judgment of decision maker in determining α. Therefore, each supply chain was ranked based on its future ideal points.

From managerial point of view, the objective of this paper is not only to supervise performance of supply chains in the past but also to plan performance of supply chains in future. In our proposed approach, managers can identify the supply chains which have the minimum gap with their goals as future efficient supply chains. On the other hand, they can identify future inefficient supply chains and provide necessary warnings to them or even cease their collaboration with them.

Further researches can be done based on the results of this paper. Some of them are as follows:

- Artificial neural networks can be used to set goals.
- In this paper we assumed that the goals are crisp. However, there might be fuzzy goals. Developing similar model to deal with fuzzy data is an interesting research topic.

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