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The performance measurement of supply chain with network DEA

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Abstract

Many of researchers and strategists believed that essence of occupation in the 21 century have been changed, and this changing would be endured with ever-increasing speed. Witness of this claim changing of produce-based work to service work and changing of old economic strategy to network economic. One of the new network economic model, is supply chain management that as collection of ways- is about management and coordination all of supply chain management. The supply chain including different dimension that to attentive to great effect in the total organization efficiency, always to notice to evaluation. Now a day's one of the ways that has great utilization in this field is a network DEA model. In this research for calculating one of the networks of supply chain, considers15 chains that including two stages, supplier and producer, and with complicated actions and reactions that to exists in the supply chain, we consider three difference to introduce in the concepts of centralism, decentralism or mixed method. In this research efficiency each one of the chain was calculated under this three control of supplying chain, then will have examine the results of each one and relation between this three controls mechanism, and at the end will be compared with classic DEA model.

Keyword: Performance Measurement, Supplying Chain, Data Envelopment Analysis, Network DEA, Efficiency.

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1. Introduction

The globalization economic and extension of information technology have been caused to changed supply-base market to demand-base market and organizations for their protection and survival discovered to importance of customer satisfaction. So supply chain management have important because need satisfaction and customers interest have accomplishing by rest of higher supplier. Therefore, with considering to this point, supply chain management (SCM) is the way to stabilize toward management and coordination all the suppliers until customer of customers [1]. In general, the supply chain is a chain that consists of the whole related action for achievement to goods process and material changes, from stage of supplying/preparation of raw material until the stage of final goods deliverance to consumer. In here except of goods process, two another process is existing, one of them is information process and another is financial resources and debts [2]. Thus the supply chain is a network of topologic organization that consists of autonomous and semi-autonomous institutions. In each of the supply chain exists an original institution that is responsible for supply chain structuring based on information related to the demand and use of financial process material and information as instrument for attain to the worth in the whole of chain [3].

One supply chain consists of the whole facilities, duties and actions that involves in produce and deliver goods or service of suppliers until customer and including planning demand and supply management, materials preparation, produce and schedule of product or service, storage, stock control and distribution, delivery and service to customer. Another word, the supply chain is set of continuous action that its start point is supplier relationship management (SRM) and its final point is customer relationship management (CRM). Kumar credits in the supply chain including manufactures, stocks, distribution centers, service centers and retail operations [4]. Goods and services can distribute by rail road, truck and by water, air, computer, post, telephone or by people. Also works and duties in the supply chain interior consist of demand or service anticipation, supplier's selection, material order, stock controls, produce planning, send and delivery, information management quality management and customer service. And any trade of organization at least is a parts of supply chain and many organizations are a parts of a multi supply chain [4].

By attention to this point that an efficient supply chain will many benefits for the organization that including expense reduction, market share increase, sold increase and stable relation to the customer. Therefore, it's clear that for success in the global markets continuously, have been evaluated performance any one of the supply chain networks. So, efficiency measurement introduces as one of the important ways of performance measurement, that results of efficiency calculation and methods so modeling, enables organizations until removing sub-organizations weakness and increasing their organization performance could be causing continuance and growth of organization [5]. Theories and different methods had presented for performance measurement of organization. this methods including: Balanced Score Card(BSC), the performance measurement matrix, performance measurement questionnaire, criteria for measurement system design and data envelopment analysis, that selection any one of this methods in order to performance measurement to depends on kind and situation of organization. In the research in order to performance measurement of supply chains will use one of the network models in the name of DEA.

Therefore, in this article we will inspect the statement of the problem, introduces of keywords, introduces conceptual model of research and models designs, index determination and specify output and input, models analysis and resulting.

2. Background

Many researchers had studied in the different field of supply chain management but limited works had done on the performance evaluation of supply chains by network models, thus in this research for chains evaluation by NDEA model considered of the chains control process that hadn't consider in the past researches. Thus, the purpose of this research with consider the inter control process.

2.1 Performance Evaluation

It's necessary any of organization adjusting use of source and power man of produce and distribution in direction of their organization objects. Institutions needs to the performance measurement system to assess their system performance and then manages their firm with gain result and for attain to the goals do the need controls [6]. Also Performance measurement can present important feedback information and managers be enable to looking on performance of organization, progress exhibit, and motivation increase and affairs recognition.

Parker states the use reasons of firm of performance measurement as follow:

- Recognizing of present situation of organization.
- Defining of this subject that do eliminate customers' needs.
- Specifying of ravines, damages, difficult and which sections needs to improvement.
- Trust to this subject do decision on the base of reality or no.
- Comparing planning with reality.

Must managers have a performance measurement system to notice to financial information and only consider financial indexes for their performance measurement [7]. In attention to this evaluation method organizations survival depend on only the profitable of that organization. With concentration to this affairs, managers had gained contrary results [8]. Then efficiency reasons of the old performance measurement system that attention to financial indexes as follow: have short time belief and profit-base, partial improvement and weak limitation in supports of continuous improvement and have a single dimension criteria's [9]. Now there is a great deal of research has been conducted on all information of each system not only financial information. This methods including: Balanced Score Card(BSC), the performance measurement matrix, performance measurement questionnaire, criteria for measurement system design and data envelopment analysis, that selection any one of this methods in order to performance measurement to depends on kind and situation of organization.

2.2 Supply chain performance evaluation

Supply chain suitable performance has an important role in success of an organization and continuous attain to a competitively advantage continuous improvement of supply chain is needs to supply chain measurement. Also Supply chain efficiency measurement are necessitating for present activities regulation of organization and new strategy creation for survival in the competitively situation, then we must look to this subject with multi dimension vision.

- Important criterions determining of the performance measurement of supply chain.

- Determining outputs and inputs of the supply chain network.
- Number and type of organizations in a supply chain determine
- Constructing the evaluation network model of supply chain. Inspection of networks efficiency.

It is necessary to say that any trade of organization at least is a parts of supply chain and many organizations are a parts of a multi supply chain so number and type of organizations in a supply chain determine by this question: is the supply chain producer or deviser?

Also works and duties in the supply chain interior consist of demand or service anticipation, supplier's selection, material order, stock controls, produce planning, send and delivery, information management quality management and customer service.

Based on above, supply chain framework is complex structure so its efficiency measurement is a more complex phenomenon and in order to Suitable supply chain measurement, we need to consider network supply chain specifications and inter contrast effects. So a non-network process cannot evaluate performance of a supply chain correctly, because doesn't include inter process of network and cannot present necessary details in order to specify in efficiency. With attention to said parameters in this field use importance of the network models is increase to evaluate and behaviors effects on each other.

2.3 Network Data Envelopment Analysis

DEA is a non-parametric technique in order to efficiency evaluation decision making units (DMU) with multi outputs and inputs [10]. This model distinguishes efficiency and non-efficiency units of one another. The extensive researches have done in the field DEA but, all of the researches don't consider presumptions related to inter operations of decision making unit, and only consider input and output of unit for evaluation then DMU is considered as black box. On the other hand, Classic models of data envelopment analysis don't create any presupposition related to the internal organization operations and consider organization as black box that only to result in outputs and inputs and give not anything comprehension of central organization process. We must attention to efficiency any of sub-units' effects on total efficiency. In addition to for the supply chains revenue, DEA models can not present particular information for how increasing of revenue. This classical method suits for the simple nature and don't evaluate correctly for the complex nature consist of supply chain that is indicate mutual relations between units [11].

These problems lead to particular kind of data envelopment analysis model that named network data envelopment analysis(NDEA), that this model can introduce inefficiency of sub-organization units. For the first time a NDEA model was introduced by Far and Grosskopf. Their new model can be evaluated network units and also it can be this models can incarnate the inter structure of networks [12]. Castelli presented a new NDEA model for fixed and related units' efficiency evaluation that in this study had been calculated efficiency evaluation the collection of the fixed and related decision making sub-units that making greater decision making units [13]. Lewis and Sexton presented a NDEA model to assess performance of a multi stage unit [11]. By using of a new network unit model, Amirtemoori and kordrostami evaluated units that contains many of continuous sub-units [14]. Yu and Lin had presented rail road performance efficiency and effectiveness by multi action data envelopment analysis models [15]. Based on parallel and series system, Kao evaluated efficiency of network units and

also each sub-unit by using of a decomposition method [16]. Wo by considering of a centralized and hierarchy structure for any of the DMU, had presented a bi-level DEA model [17]. And also for study about NDEA, you can see ([3,18,19]).

3. Proposed Model

In the below example considers one decision making unit that contains three sub-units and one of this units have inputs and outputs that builds network structure. Figure 1, exhibits outputs and inputs model and relation between sub-units of a decision making unit.

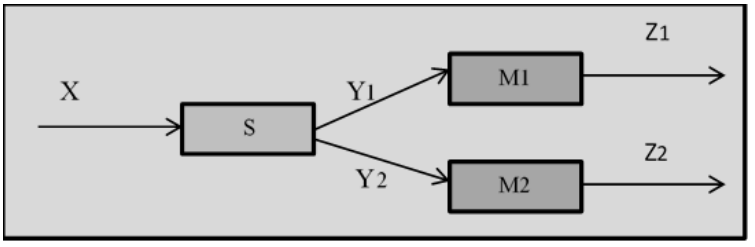

Figure1: supply chain network of the supplier-producer.

At this model have consider two stage of supply chain network that contains supplier and producer that S, M are regularly representative of supplier and producer. X is a input vector of supplier and Y_1 and $Y_2$are output vector of supplier and so these two vectors, are input vectors in the producer and Z_1, Z_2 are regularly output of m_1,m_2.

In the practicable situation of supply chain management, this chain is under demand execution in the consumer region, therefore in this model consider input tendency this model consider with reaction in supply chain therefore has been calculated the technical efficiency. [Its mean that with permitting, to coincide with middle product of supply chain outputs and inputs of network can completely evaluate. For performance measurement of this supply chain we have consider relation between this sections that forms base of the organizational control mechanism. And modeling of this DMU is based on the central control mechanism, decentral control and mix control.

If all section evaluating by a decision-maker with information attains under control, this mechanism was said central control that one decision-maker looking's on total operations for increasing efficiency. In the decentral control mechanism, isn't particular decision–maker for control of the whole section and any one of this sections have particular motivation and strategy and controls separately. In the mix control mechanism some of sections are under consideration of one decision-maker and other sections are under consideration of different decision-maker. Therefore, process (modeling) are on the base of concept of central control, decentral control and organization mix mechanism as follow:

3.1 Central control model:

In attention to s, m_1,m_2 are control by one decision-maker thus, the produce possibility collection that agreement to centralize of the supply chain as follow:

$T_{central} = \{(X, Z^1, Z^2, Y^1, Y^2) | \sum_{j=1}^{n} X_j \lambda_j^1 \leq X, \sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^1 \lambda_j^2 , \sum_{j=1}^{n} Y_j^2 \lambda_j^1 \geq$

$\sum_{j=1}^{n} Y_j^2 \lambda_j^3, \sum_{j=1}^{n} Z_j^1 \lambda_j^2 \geq z^1, \sum_{j=1}^{n} Z_j^2 \lambda_j^3 \geq Z^2 \}$

When a supply chain is an under evaluation DMU, it is evaluated with below model:

$$\text{Min } \theta_{central}$$
$$s.t.$$
$$\sum_{j=1}^{n} X_j \lambda_j^1 \leq \theta_{central} X_0 \quad (1)$$
$$\sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^1 \lambda_j^2$$
$$\sum_{j=1}^{n} Y_j^2 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^2 \lambda_j^3$$
$$\sum_{j=1}^{n} Z_j^1 \lambda_j^2 \geq Z_0^1$$
$$\sum_{j=1}^{n} Z_j^2 \lambda_j^3 \geq Z_0^2$$
$$\lambda_j^1, \lambda_j^2, \lambda_j^3 \geq 0, j = 1, \dots, n$$

And so dual of model (1) is presented as follows:

$$\max (\mu^T Z_0^1 + t^T Z_0^2)$$
$$s.t. \quad (2)$$
$$\omega^T X_j^1 - u^T Y_j^1 - v^T Y_j^2 \geq 0, j = 1, \dots, n,$$
$$u^T Y_j^1 - \mu^T Z_j^1 \geq 0, j = 1, \dots, n,$$
$$v^T Y_j^2 - t^T Z_j^2 \geq 0, j = 1, \dots, n,$$
$$\omega^T X_o^1 = 1,$$
$$\omega, u, v, \mu, t \geq 0.$$

3.2 Decentral control model:

In organization with decentral control don't exist share decision-maker for control, and any one of sections controls separately. Therefore, the produce possibility collection of this section that agreement to decentralize of supply chain as follow:

$T_{decentral} = \{(X, Y^1, Y^2, Z^1, Z^2) | \sum_{j=1}^{n} X_j \lambda_j^1 \leq X, \sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq Y^1, \sum_{j=1}^{n} Y_j^2 \lambda_j^1 \geq Y^2, \sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^1 \lambda_j^2, \sum_{j=1}^{n} Y_j^2 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^2 \lambda_j^3, \sum_{j=1}^{n} Y_j^1 \lambda_j^2 \leq Y^1, \sum_{j=1}^{n} Y_j^2 \lambda_j^3 \leq Y^2, \sum_{j=1}^{n} Z_j^1 \lambda_j^2 \geq Z^1, \sum_{j=1}^{n} Z_j^2 \lambda_j^3 \geq Z^2\}$

on this base illustrates DEA model as follow:

$$\min \quad \theta_{decentral}$$
$$s.t. \quad (3)$$
$$\sum_{j=1}^{n} X_j \lambda_j^1 \leq \theta_{decentral} X_o, \sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq Y_o^1,$$
$$\sum_{j=1}^{n} Y_j^2 \lambda_j^1 \geq Y_o^2, \sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^1 \lambda_j^2,$$
$$\sum_{j=1}^{n} Y_j^2 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^2 \lambda_j^3, \sum_{j=1}^{n} Y_j^1 \lambda_j^2 \leq Y_o^1,$$
$$\sum_{j=1}^{n} Y_j^2 \lambda_j^3 \leq Y_o^2, \quad \sum_{j=1}^{n} Z_j^1 \lambda_j^2 \geq Z_o^1,$$
$$\sum_{j=1}^{n} Z_j^2 \lambda_j^3 \geq Z_o^2, \quad \lambda_j^1, \lambda_j^2, \lambda_j^3 \geq 0, \ j = 1, \dots, n.$$

the first , eighth and ninth unequal in all of the limitations is related that firstly, the least input (x) produce in the final level z_1, z_2 outputs .

The second, third, fourth and sixth, seventh unequal coincides to middle output.

Dual of proposed model introduce as follow:

$$\text{Max } [s^T Z_0^1 + \varsigma^T Z_0^2 - (\mu - u)^T Y_0^1 - (t - v)^T Y_0^2]$$
$$s.t. \quad (4)$$
$$\omega^T X_j - u^T Y_j^1 - v^T Y_j^2 \geq 0, \ \mu^T Y_j^1 - s^T Z_j^1 \geq 0,$$
$$Y_j^2 - \varsigma^T Z_j^2 \geq 0, \quad \omega^T X_0 = 1,$$
$$\mu \geq u, t \geq v, \quad \omega, u, v, \mu, s, t, \varsigma \geq 0$$

as, any section belong to the different decision-maker, therefore, multiplier relation to final product is difference as supplier output to producer input.

3.3 Mix control model

If s, m_2 are under consideration of one decision-maker and m_1 producer is under consideration another decision-maker and with considerate to sub-collection analysis of the previous two model, the produce possibility collection of this model as follow:

$T_{mix} = \{(X, Y^1, Y^2, Z^1, Z^2) | \sum_{j=1}^{n} X_j \lambda_j^1 \leq X, \sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq Y_o^1, \sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^1 \lambda_j^2, \sum_{j=1}^{n} Y_j^1 \lambda_j^2 \geq \sum_{j=1}^{n} Y_j^2 \lambda_j^3, \sum_{j=1}^{n} Y_j^1 \lambda_j^2 \leq Y^1, \sum_{j=1}^{n} Z_j^1 \lambda_j^2 \geq Z^1, \sum_{j=1}^{n} Z_j^2 \lambda_j^3 \geq Z^2\}$

And its DEA model as follow:

$$\text{Min } \theta_{mix}$$
$$s.t. \quad (5)$$
$$\sum_{j=1}^{n} X_j \lambda_j^1 \leq \theta_{mix} X_o,$$
$$\sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq Y_o^1,$$
$$\sum_{j=1}^{n} Y_j^1 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^1 \lambda_j^2,$$
$$\sum_{j=1}^{n} Y_j^2 \lambda_j^1 \geq \sum_{j=1}^{n} Y_j^2 \lambda_j^3,$$

$\sum_{j=1}^{n} Y_j^1 \lambda_j^2 \leq Y_o^1$, $\sum_{j=1}^{n} Z_j^1 \lambda_j^2 \geq Z_o^1$
$\sum_{j=1}^{n} Z_j^2 \lambda_j^3 \geq Z_o^2$
$\lambda_j^1, \lambda_j^2, \lambda_j^3 \geq 0, j = 1, \dots, n$
And its dual planning introduces as follow:

$$\text{Max}[-(\mu - u)^T Y_o^1 + s^T Z_o^1 + s^T Z_o^1 + \varsigma^T Z_o^2] \quad s.t. \quad (6)$$
$$\omega^T X_j - u^T Y_j^1 - v^T Y_j^2 \geq 0$$
$$\mu^T Y_j^1 - s^T Z_j^1 \geq 0$$
$$v^T Y_j^2 - \varsigma^T Z_j^2 \geq 0$$
$$\omega^T X_o = 1 \; \omega, u, v, s, \varsigma \geq 0$$

4. Case study

In the supply chain network is consider two stage of network it means supplier and producer. Therefore, outputs and inputs index any one of this sections that distinguish by expert's opinion as follow:

Inputs of supplier(s):

x_1 →raw material price

x_2 →produce capacity

Outputs of supplier (inputs of producer, M^i):

y_1^1→ Expense of sending load (recepting) to the first producer.

y_2^1→ Amount of sending load (recepting) to the first producer.

y_1^2→ Expense of sending load (recepting) to the second producer.

y_2^2→ Amount of sending load (recepting) to the second producer.

Outputs of the first producer (M^1):

z_1^1→ Profile of any unit

z_2^1 → Amount of optimal produced output

Outputs of the second producer (M^2):

z_1^2→profile of any unit

z_2^2 → Amount of optimal produced outputs.

Therefore, data related to Inputs of supplier are reported in Table 1, as follows:

Table 1: Inputs of supplier

	X1	X2
DMU1	430	18000
DMU2	225	18000
DMU3	210	35000
DMU4	340	6000
DMU5	350	35000
DMU6	120	35000
DMU7	235	6000
DMU8	420	6000
DMU9	215	35000
DMU10	110	6000
DMU11	132	15000
DMU12	145	15000
DMU13	180	14000
DMU14	195	16000
DMU15	135	16000

also, data related to Supplier outputs (producer inputs) are presented in Table 2, as follow:

Table 2: Supplier outputs (producer inputs)

	Y_1^1	Y_2^1	Y_1^2	Y_2^2
DMU1	28000	2000	29000	2800
DMU2	35000	2500	36000	3300
DMU3	42000	1500	45000	2300
DMU4	42000	950	45000	1750
DMU5	64000	800	45000	1600
DMU6	70000	2000	72000	2800
DMU7	70000	1100	78000	1900
DMU8	85000	900	78000	1700
DMU9	65000	1500	90000	2300
DMU10	91000	1950	72000	1750
DMU11	26000	700	100000	1500
DMU12	35000	1650	40000	1450
DMU13	42000	700	50000	1500
DMU14	63200	650	92000	1450
DMU15	125000	800	145000	1500

finally, data related to producer outputs are shown in Table 3, as follow:

Table 3: Producer outputs

	Z_1^1	Z_2^1	Z_1^2	Z_2^2
DMU1	2200	12000	2500	8500
DMU2	2900	12000	2500	5300

DMU3	1550	8000	1500	650
DMU4	1000	8000	750	1800
DMU5	850	6500	450	6200
DMU6	2250	8700	1750	3000
DMU7	1300	9000	1250	350
DMU8	1000	6500	1500	300
DMU9	1600	7200	1500	1000
DMU10	1000	8000	3200	5500
DMU11	1900	10000	1900	5000
DMU12	700	11000	1500	12000
DMU13	700	9000	750	15000
DMU14	900	1500	4500	15000
DMU15	800	4500	4500	12000

4.1 Data analysis:

The aim of this research is supply chain performance measurement. Then, for evaluating, must to calculate the efficiency of any one of this chains or DMUS. In the below table is exhibit efficiency of any one of DMUS in attention to three organizational control mechanism and classic control model.

Table 4: Chains efficiency

	$\theta_{central}$	θ_{mix}	$\theta_{decentral}$	θ CCR
DMU1	0.2156	0.2753	0.3271	.2314
DMU2	0.2999	0.3102	0.3123	.3115
DMU3	0.3327	0.4210	0.4428	.3518
DMU4	0.4196	0.4868	0.5236	.4569
DMU5	0.2490	0.2516	0.2999	.2516
DMU6	0.5475	0.5826	0.5921	.5623
DMU7	0.4688	0.4893	0.4989	.4980
DMU8	0.5132	0.5512	0.5724	.5829
DMU9	0.3271	0.3518	0.3812	.3675
DMU10	1.0000	1.0000	1.0000	1.000
DMU11	0.5046	0.5921	0.6413	.6514
DMU12	0.5268	0.5334	0.6124	.5669
DMU13	0.6301	0.6524	0.7529	.7012
DMU14	0.6931	0.7132	0.7334	.7045
DMU15	0.8990	0.9011	0.9826	.9124

5. Discussion and conclusion

The purpose of this research is network model creation and construction to assign th supply chain performance and constructs the mathematical model for evaluation.

In order to we select effective indexes in supply chain under consideration of experts and with this index we expend multi models that evaluate supply chain performance directly and so consider relation between supplier and producer. The important problem of modeling is and how connects central products in the DEA model. Model-making of process is on the base of central control mechanism, decentral and mix organizational then with attention to this concept calculate efficiency of the organization. and with efficiency measurement under three organizational mechanisms we analysis efficiency of organization. that concludes two equal first, efficiency compare in three organizational different mechanisms: the relation between supply chain efficiency under three organizational mechanisms as follow:

Decentral control efficiency $\geq$ mix control efficiency $\geq$ central control efficiency.

The relation indicates that if supply chain in the decentral organization mechanism has a weak efficiency as a result the two mechanisms have a week efficiency too.

Second, compare of supply chain efficiency against CCR efficiency: for supply chain organizing under central control mechanism, supply chain

efficiency isn't large that calculate by black box model.

Therefore, relation between supply chain efficiency with central control and CCR efficiency as follow:

CCR efficiency≥central control efficiency.

Therefore, relation between decentral control efficiency and CCR model efficiency is different.

Briefly, we can conclude as follow:

1) For the supply chain under decentral control mechanism and mix control mechanism, that isn't right we ignore the internal organizations and consider it as a black box because in this mechanism there is more than one decision-maker.
2) In the mechanisms that all sections of supply chain are under consideration one decision-maker, and when we evaluate supply chain performance, we may select inter organization as black box. Therefore, when we ignore relation between inter products CCR model directed to great efficiency in supply chain therefore calculated efficiency isn't correct and cannot give particular information to the researcher for how increasing of efficiency. Therefore, network models have presented in this research, has done careful evaluation in regard to the classic models. And have not problems related to classic models and giving to manager necessary information for efficiency increase.
3) Propositions for future researches:

By extended use of DEA model in the different section in the field of supply chain performance measurement has not present use report of this model. That is attention to importance of supply chain performance measurement and so great capability of DEA model, use of this instrument seems perfect in this field.

In attention to in DEA classic models, don't consider inter process of decision-maker units and seeing it as black box, evaluation process does not correctly .and for an efficiency supply chain, black box method can't prepare potential information that under avail of management therefore network model has use potential in supply chain output evaluation. By now this method hadn't use in our country for performance measurement. Even, use of this method in the international level is limits, too, and so protects its newness. In the result of with being network extended system and universal competition recommends to use of this method for performance measurement of different system. and so for doing future researches recommends that instead of use of two level network that contains supplier and producer, third level that is distributor is consider for evaluation.

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