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RESEARCH ARTICLE

A DEA Based Framework to Quantify Enterprise Total Agility Index for a Holding Company

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Abstract

Agility as ability of organizations in rapid response to changing environment and responding to customer demands in today's competitive conditions is still a difficult measurement task in quantification. Due to the ambiguity of agility assessment and plentiful of enablers as well attributes, most measures are described subjectively using linguistic terms and expert opinion. There is thus, this study with a particular focus on measuring agility proposed a novel approach to assess enterprise total agility index based on agility capabilities or each enterprise divisions using a Data Envelopment Analysis (DEA) special model i.e. the common set of weights (CSW).The method is capable on using all kind of the facts and figures reveals in actual performance measures and experts' judgments. Applying such group decision-making model could conduct organizations to become more agile via detecting inefficient departments by use of a linear programming model. A case study report is presented and discussed to show the real application of the developed method.

Keywords: *Data Envelopment Analysis, Total Agility Index, Common set of weights.*

Introduction

In the context of production, agility can be defined as the state or quality of being able to change quickly with demand volatility and timely manner in an easy fashion [1]. The concept of agility stems from the literature on flexibility in economics and was initially developed by a group of researcher's in1991 at the Iacocca Institute. They defined agilityasa manufacturing system with extraordinary capabilities to meet the rapid changing needs of the market lace(speed,flexibility,customers,competitors,suppliers,infrastructure and responsiveness).Further definitions were provided by Dove R & Sambamurthy V, Bharadwaj A, Grover V [2-3].

Babazadeh Reza , Razmi Jafar, Ghodsi Reza [4] itemized that agile practices may be recognized through four factors; Market sensitive, Virtual integration; Network-based and Process integration. It is related to a high level of integration between partners within a supply chain and enables collaborative working methods such as joint product design. Consequently, the partners possibly will be able to advance an assortment of products and deal with ambiguity.

The concept of knowledge management and responsibility as being the two cornerstone so fagility was furt here laborated by Dove R [5] where hestated that the Agility is equal to ResponseAbility+KnowledgeManagement.Hethen subsequentlystrengthenedhisdefinitionbystatingthatinorderforasystemtobeagile,itmustefficientlyandcreativelyrespondtobothproactiveandreactiveneedsandopportunities whent hese are unpredictable, uncertain and are likely to change [6].

Some researcher agile methods in designing a supply chain network. Many of them are able to integrate production, outsourcing, flexibility, and distribution activities by considering the most important factors of the agile supply chain. A recent report proposed by Babazadeh Reza , Razmi Jafar, Ghodsi Reza [4] which focused on the locations of facilities in the supply chain network design, and integration of facility location decisions with other decisions such as outsourcing, inventory control, production, etc. to improve supply chain agility in terms of performance and responsiveness.

A broad review on more than 70 papers on agile manufacturing literature was performed by Sanchez LM, Nagi R [7] this deeply discussed on agile attributes, agile enablers and methodologies to achieve agility. Bohdana Sherehiy, Waldemar Karwowski, John K Layer [8] reviewed large number of papers related to the agile manufacturing on concepts, frameworks, and attributes of enterprise agility. Wen-Pai Wang [9] surveyed many papers on dimensions of agility evaluation and he developed a 2-tuple fuzzy linguistic evaluation model for selecting appropriate agile manufacturing system. Agarwal A, Shankar R, Tiwari MK used interpretive structural equation modeling (SEM) approach to investigate interrelationships of the variables influenced on supply chain agility.

Through the present article we use Data Envelopment Analysis (DEA) and common set of weights (CSW) on the agility framework derived from the Dove agility definition [2]. For more detail on CSW interested people may refer to ((Raissi, S., Izadi, M., Saati, S., 2011), (Raissi S., Izadi M., Saati S., 2012) [11,12].

In Section 2, we provide details of common set of weight, which applied on the methodology. The proposed five-step procedure to quantify a novel index presented in Section 3. In Section 4, we presented a case study to get more focus on the proposed methods. We conclude the paperwith some remarks in Section 5.

Common set of Weight Model

Consider a case of data envelopment model consist of n decision-making unit; DMU, each one consumes varying amounts of m different inputs to produce s outputs. In the model formulation, $x_{ip};(i=1,\dots,m)$ and $y_{rp};\ (r=1,\dots,s)$ denote, respectively, the nonnegative input and output values for DMU $_p$, under consideration. Also, suppose $u_r;(r=1,\dots,s)$, $v_i;(i=1,\dots,m)$ are the weights associated with input i and output r, respectively.

In addition U_r^l, U_r^u, V_i^l and V_i^u are lower and upper bounds on output and input weights, respectively. When no flexibility is allowed in DEA for assigning the individual set of weights to each of the participating DMU, here a common set of weight model(CSW) is act as alternative method to solve the problem [13].

A two-step method could be applied to obtain efficiency of each DMU. In step 1 upper bound of output weights is calculated using model 1.

$$\begin{aligned} & Max\, u_r \\ \text{S.t}\quad & \sum_{\mathrm{I}=1}^{\mathrm{m}} v_i x_{\mathrm{ij}} \le 1\ ;\forall \mathrm{j} \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0\ ;\ j=1,2,\dots,n \\ & u_r, v_i \ge 0\ \forall r, i\ ; i=1,\dots,m\ ; r=1,\dots,s \end{aligned} \qquad (1)$$

In second stepa CSW model 2 is applied.

$$\begin{aligned} & Max\ \emptyset \\ S.t\quad & U_r^l + \emptyset(U_r^u - U_r^u) \le u_r \le U_r^l + \emptyset(U_r^u - U_r^u);\forall r \\ & V_i^l - \emptyset(V_i^u - V_i^u) \le v_i \le V_i^l - \emptyset(V_i^u - V_i^u)\ ;\forall i \end{aligned} \qquad (2)$$

Consequently, the efficiency of each DMU could be evaluated based on Eq. 3

$$e_j = \frac{\sum_{r=1}^{s} u_r^* y_{rj}}{\sum_{i=1}^{m} v_i^* x_{ij}} \quad ;\forall j \qquad (3)$$

where, $u_r^*(r=1,\dots,s)$ and $v_i^*(i=1,\dots,m)$ are optimalvalues of model 2.

The Proposed Methods

Consider an enterprise has$n$ Company/division or branches and their performances reported periodically. Here, figures encounter ambiguity to describe total enterprise agility, meanwhile some features of agility capability may reveals in data. Our proposed method to evaluate an aggregate index for total agility consists of a few systematic steps as:

Step1) to identify a list consists of s agility capability features. They appear some aspects of enterprise agility in terms of responsiveness, competency, flexibility and quickness.

Step 2) to evaluate historical performances of p divisions per each agility capability. This evaluation process may take into accounts some objective/subjective inferences.

Step 3) Developing a DEA model such as presented on Section 2, to evaluate efficiency of each enterprise division. The GAMS™ software could be used to solve the models to attain efficiencies of each DMU.

Step 4) Identification of efficient and inefficient DMU: By using the results of the Model and applying Eq. 6, the efficiencies of each DMU could be calculated.

Step 5) Calculating the total agility index. The Eq.4 presents an aggregated mean efficiency of each DMU and could be calculated periodically when e_j has slim variation among their expected value of $\bar{E}$ .In broad dispersion, an interval estimating of the true mean efficiency of DMUs based on a given reliability level is more appropriate. Practitioners could apply a weight vector for DMU based on their size, importance or any other preferences. Eq. 4presents the centrality of agility index, which derived from the geometrical mean of different efficiencies. So, the proposed mean agility index could nominate as a measure of quantifying total agility index and may be plotted or monitors over time using control charts or to trace for the trends.

$$\bar{E} = \sqrt[n]{\prod_{j=1}^{n} e_j} \qquad (4)$$

Case Study

In this section, the proposed algorithm is applied in a holding private company active in electronics and telecommunications industries. This company has 12 branches around the Middle East.

Initially we gathered twenty-two top managers, engineers, academia and a few representatives of supplier and whole sales to identify candidate factors affecting on the enterprise agility. Many rounds of discussion on factors derived from the literature survey and experts' opinions conduct us to a preliminary list. Brainstorming sessions were conducted where revealed that thirteen variables could quantify enterprise agility level. Questionnaire based survey was conducted to rank these output variables. Imperative structural modeling approach and MICMAC analysis technique identified that three of them were falling into the category of autonomous variables, so they discarded from more analysis and the research work had been continued with the remaining ten variables. Analysis showed that autonomous variables have weak driver power and weak dependence. These variables are relatively disconnected from the system, with which they have only few links, which may not be strong and hence, may be discarded. Here in after a set of ten output variables nominates by $O_l; l = 1, \ldots, 10$. All of these outputs reflect a dimension of enterprise agility capability in responsiveness, competency, flexibility and quickness.

In order to evaluate the annual performance of each twelve branches of the holding company, all of the 22 experts filled a questionnaire which designed using a five point Likert-type scale ranging from 1= 'Weak score' to 5 = 'very high score'. Hence, experts asked to score each branch performance per outputs variables based on some fact and figures documented relevant to 2013 in databases and their inferences. Throughout the data gathering, participants are clearly informed that their responses are anonymous and confidential and that their participation is voluntary.

In the case study, each branch acts as a DMU. This case also embeds 10 outputs variables. Table 1. Average score of each all the 22 experts for each DMU per each agility capability feature.

Table 1: Mean performance score of each branch per agility capability features

Branch (DMU) #	O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8	O_9	O_{10}
1	2.98	2.9	3.01	2.92	2.8	3.01	3.05	2.82	2.88	2.87
2	2.98	3.25	2.91	3.9	3.38	2.91	3.11	3.52	2.98	3.1
3	3.74	3.35	2.9	3.4	2.94	3.07	3.07	3.42	2.98	2.87
4	3.24	2.88	3.14	3.15	3.05	3.17	3.76	2.96	3.2	2.57
5	2.84	3.01	2.91	3.05	3.14	4.15	2.96	3.08	2.97	1.87
6	2.98	2.95	2.98	3	2.71	3.76	4.02	2.98	3.08	2.82
7	2.74	2.67	2.98	2.12	3.17	2.82	2.94	3.06	3.05	2.77
8	3.14	3.14	3.2	2.78	3	3.8	3.76	3.22	2.98	3
9	3.56	2.75	3.21	3.47	2.85	3.35	3.04	3.5	2.91	3.3
10	2.08	2.72	2.91	2.52	3.35	2.81	3.01	2.4	3.06	3.4
11	3.02	2.98	2.8	3.07	3.08	3.47	2.98	3.38	3.08	2.82
12	3.08	2.62	2.93	2.55	2.94	2.81	3.62	3.08	2.92	3.42

In order to apply a CSW model, one dummy input variable considered. Table 2 presents the calculated weights for each agility capability.

Table 2: Weights of each 10 agility capability features derived from applying a CSW model

w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}
0.0267	0.0298	0.0311	0.0256	0.0296	0.0241	0.0249	0.0284	0.0312	0.0292

Consequently, the degree of annual efficiency of 2013for each enterprise branch presented in Table 3.

Table 3: Results of efficiency units

Branch #	1	2	3	4	5	6	7	8	9	10	11	12
Efficiencies	0.91	1	0.99	0.97	0.93	0.97	0.89	1	0.99	0.89	0.96	0.94

Therefore, the total enterprise agility index in 2013 could be obtained from the geometric mean of all 12 efficiencies and may be traced over the time.

$$\bar{E} = \sqrt[12]{0.91\times 1\times 0.99\times 0.97\times 0.93\times 0.97\times 0.89\times 1\times 0.99\times 0.89\times 0.96\times 0.94} \cong 0.96$$

Here, efficiency index of each braches lies between 0.93 and 1.00. This range reveals that there is no significant variation between each branch's efficiency, so total agility index, which derived from the geometrical mean of equally weighted is on a good range. Therefore, the proposed mean agility index could nominate as a measure of quantifying total agility index and possibly will be compared with the prior or posterior values.

Conclusion

Through this article, a method to estimate an enterprise agility index is proposed. Proposed method is easy to apply and works based on both the real performance documented data ad experts' justifications. Manipulative to such index needs to solve a suggested linear mathematical programming using a standard computer package such as GAMS. In any standard outputs of solving the model, efficiency of each division (departments/company) could be achieved. Perhaps realizing holdings to 100 percent agility is very ideal, but try to increase level of agility is an efficient challenge for organizations i.e. always be ready to serve customers, identify hide and reveal needs and thus achieve a unique position in today's turbulent environment. This research report was shown that total agility index can be estimated using any aggregation statistics such as point or interval estimation of the true enterprise mean, which lies between 0 and 1.

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