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Learning Improvement of DEA Technique in Decision Making for Manufacturing Applications Using DEA Excel-Solver

Atefeh Amindoust [1, a], Shamsuddin Ahmed [1, b] and Ali Saghafinia [2, c]

[1] Engineering Design & Manufacture Department, University of Malaya Kuala Lumpur, 50603, Malaysia

[2] Electrical Engineering Department, Islamic Azad University, Majlesi Branch, Esfahan, Iran

[2] Electrical Engineering Department, University of Malaya Kuala Lumpur, 50603, Malaysia

[a] Atefeh_Amindoust@yahoo.com, [b] Ahmed@um.edu.my, [c] Saghafi_Ali@yahoo.com

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Abstract. DEA (Data Envelopment Analysis) is the optimization method of mathematical programming to measure the relative efficiencies of decision making units (DMUs). Due to its wide applicability, the DEA has been studied extensively for the last 30 years to solve decision making problems. Since, there are a lot of selection decisions in manufacturing, DEA as an appropriate tool to be necessary-especially for engineers- to improve learning for decision making. In this paper, the DEA method is applied in decision making process through DEA Excel-Solver software and the required processes are explained step by step to help academics and practitioners to get appropriate results in making decision.

Introduction

Industrial engineering is a branch of engineering dealing with the optimization of complex processes or systems. The various topics concerning industrial engineers include management science, financial engineering, engineering management, supply chain management, process engineering, operations research, systems engineering, ergonomics / safety engineering, cost and value engineering, quality engineering, facilities planning, and the engineering design process [1, 2].

Operations research (OR) is a discipline which deals with the application of advanced analytical methods to help make better decisions [3]. It is often considered to be a sub-field of mathematics [4]. The OR encompasses a wide range of problem-solving techniques and methods applied in the pursuit of improved decision-making and efficiency, such as simulation, mathematical optimization, queuing theory and other stochastic-process models, Markov decision processes, econometric methods, data envelopment analysis, neural networks, expert systems, decision analysis, and the analytic hierarchy process [5]. Nearly all of these techniques involve the construction of mathematical models that attempt to describe the system. Because of the computational and statistical nature of most of these fields, OR also has strong ties to computer science and analytics.

However, the OR course will touch on more complex models. The main emphasis will be on solution techniques and on analysis of the underlying mathematical structure of these models. As a supporting theme, the course will also emphasize the use of mathematical solvers [6]. In all of the aforementioned scenarios, decision making issue may be one of the main components and the engineering side tends to emphasize extensive mathematical proficiency and usage of quantitative methods to make decisions.

Data envelopment analysis (DEA) is a nonparametric method in operations research for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units (or DMUs). Due to the wide applications of DEA in deferent area [7-10], software is no longer an impediment to the incorporation of this technique into decision-support systems. DEA as an educational tool to be necessary-especially for students- to improve learning for decision making in conducting operation research course. So, the DEA Excel Software as a useful package is described and presented in this paper to make decisions.

DEA Approach

DEA is a mathematical programming method which was proposed by Charnes et al (1978) to evaluate the relative efficiency of decision making units (DMUs) by multiple inputs and outputs but with no obvious production function to aggregate the data in its entirety [11]. Relative efficiency is defined as the ratio of total weighted output to total weighted input. By comparing p units with J outputs denoted by y_{js} (the amount of output j provided by unit s), $j = 1,2,...., J$, and l inputs denoted by x_{ls} (The amount of input l provided by unit s), $l = 1,2,...., L$, the efficiency measure for s th unit ($s = 1,2,...., p$) is obtained as below.

$$h_s = \underset{u_j, v_l}{Max} \frac{\sum_{j=1}^{J} u_j y_{js}}{\sum_{l=1}^{L} v_l x_{ls}} \tag{1}$$

where, the variables u_j and v_l are the weights of outputs and inputs, respectively which are non-negative and obtained by the model. A second set of constraints requires that the same weights, when applied to all DMUs, do not provide any unit with the efficiency greater than one. This condition appears in the following set of constraints:

$$\frac{\sum_{j=1}^{J} u_j y_{j\lambda}}{\sum_{l=1}^{L} v_l x_{l\lambda}} \leq 1 \qquad , \lambda = 1,2,...., p \tag{2}$$

where, λ is the weights of outputs and inputs. The efficiency ratio ranges from zero to one, with DMU s being considered relatively efficient if it receives a score of one. Thus, each unit will choose weights so as to maximize self-efficiency, given the constraints. The result of the DEA is the determination of the hyper planes that defines an envelope surface or Pareto frontier. DMUs that lie on the surface determine the envelope and are deemed efficient, whilst those that do not are deemed inefficient [12].

Many different DEA models have now appeared in the literature such as input-oriented, output-oriented, constant return to scale (CRS), and variable return to scale (VRS) and so on. (Readers are referred to [13] for more detailed information).

DEA Excel Solver Software

As the field of Data Envelopment Analysis has grown and blossomed, so have the varieties of models, data, and types of analyses. Similarly, as DEA software technology has emerged from its academic roots into production usage, it has been accompanied by expectations of advanced modeling options and professional implementations, including graphical user interfaces, interoperability with other applications, and the ability to quickly evaluate large populations[14]. One of the popular DEA solution systems is a DEA Excel Solver which is distributed at little or no cost. The DEA Excel Solver software is documented in[15] and its system requirements are Microsoft Windows and Microsoft Excel. DEA Excel Solver provides researchers and practitioners an extensive collection of models and an appealing user interface. It is an impressive contribution to DEA research and industry application. The complete explanation of this software along with an example will be shown in next section.

Application of DEA Excel Solver in Decision Making

To handle decision making problems using DEA Excel Solver package, the DMUs in the decision process must be identified firstly. Then, the amount of inputs and outputs which applied in DEA method must be determined. In this paper, a numerical example has been applied which included 15 DMUs with 3 inputs and 2 outputs. When loaded, the Microsoft Excel add-in appends a "DEA" drop-down menu to the standard menu bar, from which specific models and actions can be invoked as shown in Fig.1.

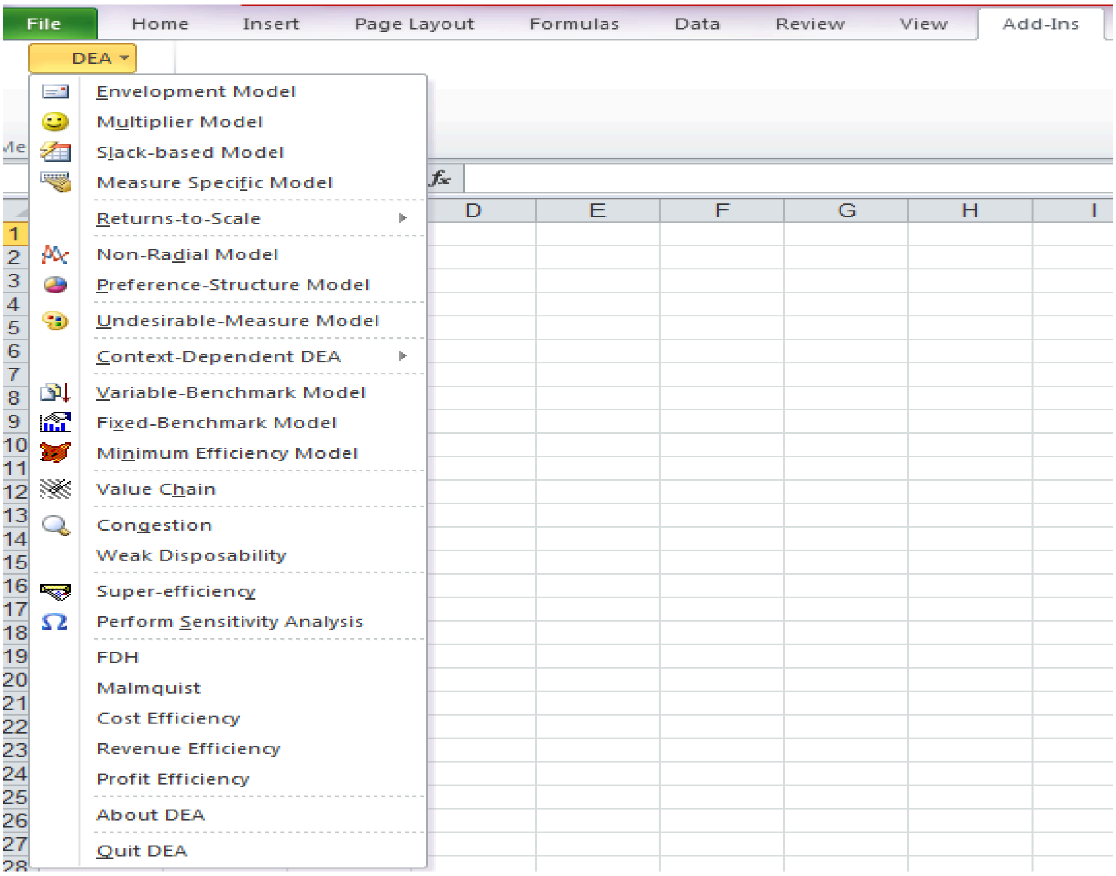

Fig. 1. Drop-down menu of Add-Ins in DEA Excel Solver

User-provided data and processing results are stored as different worksheets in a common file. The population data is supplied as columns containing: DMU names, input values (C1, C2, and C3), a blank column, and output values (C4 and C5) as shown in Table 1.

Among all of the options in drop-down menu, some more popular options have been selected in this paper as seen below.

Table 1. Numerical example

DMU No.	C1	C2	C3		C4	C5
1	91920.6	10950	36000		184365.2	346.2
2	68770.9	5553.9	80000		181518.7	314.8
3	65708.9	4271.1	7182		169164.6	121.2
4	217123.4	23345.5	709000		168828.6	6880.7
5	50268.9	6681	6193		167530.7	210.5
6	71439.3	5239.1	6702		161057.4	156.6
7	243283	24547	346990		137137	4139

8	106004.2	49691.6	146855		111052	2662.4
9	91296	40436	82000		110009	6470
10	118011.6	58986.4	104000		109833.7	6904.6
11	37871	14762	675000		93627	2740
12	91620.9	29907.2	331852		84167.1	1468.8
13	364762.5	2241.9	89690		83206.7	2426.6
14	127077.3	42240.1	231400		81937.2	2209.1
15	88884	17274	299300		79609	139

After choosing each of the options, two questions appear. The first one is related into your idea about input-oriented or output-oriented manners (which one do you want to select?). The other one is about CRS and VRS models (which one do you want to select?).

For example for the first option "Envelopment Model", the input-oriented and CRS modes have been considered as seen in Table 2.

It is found out from the table above; seven DMUs are efficient (2, 3, 4, 5, 9, 11, and 13) and other remained eight DMUs are inefficient. Also, the benchmark scenario was done for the inefficient units. For every inefficient unit, DEA identifies a set of efficient units that can be utilized as benchmarks for improvement of inefficient units. In fact, shadow prices (λ) that are not equal to zero, make dummy units with composition of reference sets for evaluation. These results have been presented in Table 2. For example, DMU1 is an inefficient unit and the dummy unit can be made with DMUs 3, 4, 5, 11 (references) with multipliers 0.184, 0.017, 0.893, and 0.008(λ values or shadow prices). So, the obtained dummy unit is an efficient unit instead of DMU1.

After selecting the second option "Multiplier Model" considering input-oriented and VRS modes, the related results can be obtained in Table 3.

Table 2. The results of "Envelopment Model" option

DMU No.	Input-Oriented CRS Efficiency	**Benchmarks**							
1	0.66283	0.184	3	0.017	4	0.893	5	0.008	11
2	1.00000	1.000	2						
3	1.00000	1.000	3						
4	1.00000	1.000	4						
5	1.00000	1.000	5						
6	0.97197	0.547	3	0.408	5	0.001	9		
7	0.73717	0.253	3	0.305	4	0.233	9	0.206	13
8	0.52456	0.382	5	0.371	9	0.066	11		
9	1.00000	1.000	9						
10	0.84142	1.067	9						
11	1.00000	1.000	11						
12	0.38606	0.312	5	0.145	9	0.169	11		
13	1.00000	1.000	13						
14	0.34858	0.012	4	0.247	5	0.291	9	0.069	11
15	0.27038	0.467	5	0.015	11				

By choosing this model, five DMUs (7, 8, 12, 14, and 15) are inefficient and the remained others are efficient. Also, the optimal multipliers have been derived through this model. As you seen in table above; some multipliers are equivalent to zero. It seems it is not logic, because in this way some criteria have not been considered in decision process. May be this is one of the shortcomings of DEA.

Table 3.The results of “Multiplier Model” option

DMU No.	Input-Oriented VRS Efficiency	Optimal Multipliers C1	C2	C3	C4	C5
1	1.0000	0.00000	0.00007	0.00001	0.00004	0.00083
2	1.00000	0.00001	0.00007	0.00000	0.00001	0.00026
3	1.00000	0.00001	0.00008	0.00000	0.00001	0.00056
4	1.00000	0.00000	0.00002	0.00000	0.00000	0.00013
5	1.00000	0.00002	0.00000	0.00000	0.00001	0.00019
6	1.00000	0.00000	0.00009	0.00008	0.00000	0.00140
7	0.73756	0.00000	0.00002	0.00000	0.00000	0.00014
8	0.60325	0.00001	0.00000	0.00000	0.00000	0.00006
9	1.00000	0.00000	0.00002	0.00000	0.00000	0.00013
10	1.00000	0.00001	0.00000	0.00000	0.00000	0.00052
11	1.00000	0.00001	0.00004	0.00000	0.00000	0.00027
12	0.55760	0.00001	0.00000	0.00000	0.00000	0.00007
13	1.00000	0.00000	0.00005	0.00000	0.00000	0.00035
14	0.47061	0.00001	0.00000	0.00000	0.00000	0.00005
15	0.53354	0.00001	0.00000	0.00000	0.00000	0.00000

After choosing the third option “Slack-based Model”, as seen in Table 4 the value of input slacks for efficient units must be zero. If the values are not equivalent to zero, it shows that this unit is inefficient. For example, in case of DMU1 the input slacks for C3 and C4 are not zero. It can be shown that DMU1 is inefficient.

Table 4.The results of “Slack-based Model” option

CRS Results	*Input Slacks*			**Output Slacks**	
DMU No.	*C1*	*C2*	*C3*	**C4**	**C5**
1	0.00000	0.00000	24871.42345	107334.93962	0.00000
2	0.00000	0.00000	0.00000	0.00000	0.00000
3	0.00000	0.00000	0.00000	0.00000	0.00000
4	0.00000	0.00000	0.00000	0.00000	0.00000
5	0.00000	0.00000	0.00000	0.00000	0.00000
6	12794.20221	0.00000	0.00000	5857.51388	0.81297
7	0.00000	0.00000	11105.20622	301650.00146	0.00000
8	0.00000	25289.02924	108011.55489	171436.82714	0.00000
9	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.00000	13499.35986	14957.88042	78912.17949	0.00000
11	0.00000	0.00000	0.00000	0.00000	0.00000
12	0.00000	12685.38884	307952.81488	186551.33195	0.00000
13	0.00000	0.00000	0.00000	0.00000	0.00000
14	0.00000	17554.48860	196254.33495	288061.84791	0.00000
15	0.00000	5460.85104	288349.71837	216613.88807	233.19995

Conclusion

Decision making is an important part of all science-based professions, where specialists apply their knowledge in a given area to making informed decisions. Since there are a lot of alternatives in terms of evaluative criteria in the decision process, there is a need to find appropriate methods to make decisions. One of the most popular techniques in this area is DEA. In addition, due to the wide applications of DEA, software is no longer an impediment to the incorporation of this technique into decision-support systems. The DEA Excel Solver as the related software to DEA provides an abundance of model choices, many of which are unique to this package. Its rich feature set provides sensitivity analyses, benchmarking evaluations, super efficiencies, and so on. Also, color-coding as an advantage designates different sections within related tables.

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