Evaluation and ranking of manufactured cars in Iran using Network Data Envelopment Analysis model

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Abstract: Data Envelopment Analysis (DEA) is a mathematical programming-based approach to evaluating and ranking decision-making units (DMUs) with multiple inputs and outputs. These DMUs can be banks, various organizations, or even factory-manufactured cars. Network Data Envelopment Analysis (NDEA) is an extension of the DEA that considers intermediate structures in performance evaluation for DMUs. The purpose of the present paper is to evaluate and rank cars using the NDEA technique. As such we first present two models of NDEA including a multiple form and envelopment form for a simple two-step process in network data envelopment analysis. Finally, using the two models presented, 43 cars manufactured in the Iranian auto factories are ranked.

Keywords: Ranking, Evaluation, Network Data Envelopment Analysis, Automotive.

1. Introduction

As the markets in Asia become bigger and more important, their influence on the world business is increasing rapidly. For the past ten years, Iran has been a major auto producer in the world. Now Iran is the 12th largest automaker in the world and the largest in the middle-East showing that there is an important potential for Iran in the auto industry.

The world automotive industry, which dates back more than a century and has extensive back-and-forth connections with other industries, plays an important role in the industrial development planning of countries, especially the developing countries, hence making it the "industry of industries" (Valibeigi, Fahimifar, Abedinzadeh, 2004).

Data envelopment analysis (DEA) is a non-parametric mathematical programming-based method for evaluating the performance of a set of decision-making units (DMUs) with multiple inputs and outputs. Farrell (1957) first proposed non-parametric methods for determining efficiency. His work was generalized and presented as the Data Envelopment Analysis leading to the CCR paper (Charnes, Cooper, and Rhodes, 1978). In the CCR paper, the multi-input efficiency of a single Farrell output is generalized to the multi-input mode of multiple outputs. In 1984 the BCC article was published by Banker, Charnes, and Cooper (Banker, Charnes, and Cooper, 1984). In addition to the models presented in the CCR and BCC articles, other basic models such as collective models and SBMs have been proposed (Tone, 2001). All of these models are assumed to be classic DEA models. Many researchers have recently reviewed data envelopment analysis models, for example, Emrouznejad et al. (2017) reviewed data envelopment analysis models in its fourth decade.

In the classic DEA models, DMUs are considered as black boxes and do not take into account their intrinsic activity and structure (Sexton et al., 1986; Kao, 2009; Holod and Lewis, 2011; Moeini et al., 2015; Karimi et al., 2015). In a decision-making unit, inputs may pass through multiple processes to become outputs. In traditional and classic DEA models, which consider the DMU as a black box, a layer of DMU may work while its subdivisions are ineffective (Kao and Hwang, 2010).

Due to the weakness of traditional models for examining the internal structure and ignoring input activities, researchers have made great efforts to develop traditional models to examine multi-stage DMUs. Separating the bank performance into two successive stages of profit and marketing, Seiford and Zhu (1999) attempted to abandon the traditional box-office approach in evaluating the bank and incorporate the internal structure, but they were independent of the two traditional DEA

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models (Seiford and Zhu, 1999). They used the evaluation of these two stages and ignored the transfer of information between the two stages. In some two-stage models where the outputs of the first stage are used as the inputs of the second stage, it is required to reduce the inputs to make it work if the second stage fails, but lowering the input of the second stage means reducing the output of the first stage. It causes the first stage to fail (Cook et al., 2010). In this type of research, although the internal structure is considered, incomplete evaluations were provided due to the lack of consideration of subunit communication and transfer of information from one step to the next.

To address the flaws of traditional and standalone models, Färe and Grosskopf (2000) introduced NDEA models that examine the process operation of components in evaluating the performance of multi-stage DMUs (Färe and Grosskopf, 2000). They proposed three types of models based on the work of Färe et al. (1996) that considered the internal structure and interactions of components (Färe and Grosskopf, 1996). After Färe and Grosskopf (2000), other researchers developed NDEA models (Färe and Grosskopf, 2000). Unlike the classic models, the NDEA models of a standard form of Kao (2009a) and their models depend on the structure of the DMU and how its sub-components relate to the type of inputs and outputs (Kao and Hwang, 2010).

Despotis, Koronakos, and Sotiros (2016) used a weak-link approach to provide a simple two-step model for evaluating the efficiency of DMUs. Khoveyni, Fukuyama, Eslami and Yang (2019) examined the concept of variations effect in a two-stage NDEA to see what output products would change if intermediate products increased with increasing inputs in the first stage. On the other hand, even with the same structure, several different models with different approaches and perspectives may be offered for a particular structure (Kao, 2009b; Lim and Zhu, 2019).

The present paper firstly introduces network data envelopment analysis models. These models are presented in both Multiple and Envelopment forms for a simple two-step network. In the Multiple form, using the step-by-step evaluation models, a two-objective model is presented to evaluate the two-stage performance and using the weighted approach, the two-objective problem becomes a single-objective one. The Envelopment form uses a two-stage non-radial approach to evaluate performance. Finally, using the models presented in the paper, the ranking of cars in the automotive industry in Iran is discussed. The organization of the paper is as follows: The following section presents the mathematical models presented in the paper, which include Multiple and Envelopment form. In the third section, using the models presented, the manufactured cars of Iranian factories are ranked. Conclusions and suggestions will be presented in Section 4.

2. Methodology

The purpose of this section is to introduce two-stage network models for performance evaluation. In this section, each DMU converts input X to the final output Y through the intermediate capacitance Z in a two-step process shown in Figure 1.

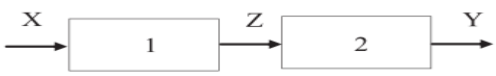

Figure 1. A simple two-step process

The Network Data Envelopment Analysis models presented in this section include the Multiple and Envelopment forms that will be discussed further.

2.1. NDEA Model in the Multiple Forms

Suppose we have n DMUs. According to Figure 1, these DMUs consist of two steps, in the first step the X input becomes the Z output. To evaluate the performance of DMU_O (o = 1, ..., n), at this stage, we use the input-based Multiple model by assuming a constant to return scale as follow:

$$E_o^1 = \max \frac{\sum_{t=1}^{p} w_t z_{to}}{\sum_{i=1}^{m} v_i x_{io}}$$

$$s.t. \quad \sum_{t=1}^{p} w_t z_{tj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1,..., \mathrm{n}$$

$$v_i \ge 0, \quad w_t \ge 0 \qquad (1)$$

$$(i = 1,..., m; t = 1,..., p)$$

In the above model, the variables v_i and w_t are the weights corresponding to the inputs and outputs of DMU_O , respectively. The value of the optimal objective function E_o^1 corresponds to the performance score of DMU_o in step (1). But in step (2) the Z input becomes the Y output.

Also, to evaluate the performance of DMU_O (o = 1, .., n) at this stage, we use the input-based Multiple model assuming a return to the following scale:

$$E_o^2 = \max \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{t=1}^{p} w_t z_{to}}$$

$$s.t. \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{t=1}^{p} w_t z_{tj} \le 0 \qquad j = 1,..., \mathrm{n}$$

$$u_r \ge 0, \quad w_t \ge 0 \qquad (2)$$

$$(\mathrm{r} = 1,..., \mathrm{s}; t = 1,..., p)$$

In this model, the variables w_t and u_r are the input and output weights in step (2), respectively, to evaluate DMU_O The efficiency at this stage is also equal to the value of the optimal objective function of the model (2) or E_o^2.

In data envelopment analysis, we always seek to maximize efficiency. Now, to evaluate network performance, we have to combine the two models above. The model should maximize the performance of both steps simultaneously. To do this, we present the following two-objective model for evaluating two-stage network performance that simultaneously maximizes the efficiency of the steps:

$$E_o^1 = \max \frac{\sum_{t=1}^{p} w_t z_{to}}{\sum_{i=1}^{m} v_i x_{io}}$$

$$E_o^2 = \max \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{t=1}^{p} w_t z_{to}}$$

$$s.t. \quad \sum_{t=1}^{p} w_t z_{tj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1,\ldots,\mathrm{n}$$

$$s.t. \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{t=1}^{p} w_t z_{tj} \le 0 \qquad j = 1,\ldots,\mathrm{n}$$

$$u_r \ge 0, \quad w_t \ge 0, \quad v_i \ge o \tag{3}$$

$$(\mathrm{i} = 1,\ldots,\mathrm{m}; \qquad \mathrm{r} = 1,\ldots,\mathrm{s}; \qquad t = 1,\ldots,p)$$

In multi-objective planning literature, there are several approaches to multi-objective problem solving (Ehrgott, 2000; Karimi and Karimi, 2017). Applying the weighted approach, the model (3) is written as a single purpose one:

$$E_o = \max(\mathrm{w}_1 \frac{\sum_{t=1}^{p} w_t z_{to}}{\sum_{i=1}^{m} v_i x_{io}} + w_2 \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{t=1}^{p} w_t z_{to}})$$

$$s.t. \quad \sum_{t=1}^{p} w_t z_{tj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1,\ldots,\mathrm{n}$$

$$s.t. \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{t=1}^{p} w_t z_{tj} \le 0 \qquad j = 1,\ldots,\mathrm{n}$$

$$u_r \ge 0, \quad w_t \ge 0, \quad v_i \ge o \tag{4}$$

$$(\mathrm{i} = 1,\ldots,\mathrm{m}; \qquad \mathrm{r} = 1,\ldots,\mathrm{s}; \qquad t = 1,\ldots,p)$$

where w_1 and w_2 are the weights for the first and second targets, respectively, which must be non-negative and the sum must be 1. Its values are also determined by the decision-maker. This model simultaneously delivers the efficiency of steps and the entire network simultaneously. Suppose (v_i^*, w_t^*, u_r^*) is the optimal solution of the model (4). The efficiencies of the steps and the entire network are then calculated as follows:

$$E_o^1 = \max \frac{\sum_{t=1}^{p} w_t^* z_{to}}{\sum_{i=1}^{m} v_i^* x_{io}}, \qquad E_o^2 = \max \frac{\sum_{r=1}^{s} u_r^* y_{ro}}{\sum_{t=1}^{p} w_t^* z_{to}}, \qquad E_o = \max(w_1 \frac{\sum_{t=1}^{p} w_t^* z_{to}}{\sum_{i=1}^{m} v_i^* x_{io}} + w_2 \frac{\sum_{r=1}^{s} u_r^* y_{ro}}{\sum_{t=1}^{p} w_t^* z_{to}})$$

Note that network efficiency is a weighted average of steps' efficiency. In the following section, we calculate network efficiency in the Multiple form. The following section presents the network efficiency evaluation model in the Envelopment form.

2.2. Data Envelopment Analysis Model of the Network Data in the Envelopment Form

In Multiple models, a variable weight is considered for the input, middle, and output criteria and the efficiency score is calculated as the output weighted ratio to input weighted ratio to maximize it. But in the Envelopment form, a set of outputs is constructed and the maximum ratio of input or output reduction of the decision unit under evaluation is calculated. The purpose of this subsection is to present a two-step data Envelopment analysis model in the Envelopment form. The following NDEA model is used:

$$E_o = \min \frac{\frac{1}{m+s}(\sum_{i=1}^{m}\theta_i + \sum_{t=1}^{p}\alpha_t)}{\frac{1}{s+p}(\sum_{r=1}^{s}\varphi_r + \sum_{t=1}^{p}\beta_t)}$$

$$s.t. \quad \sum_{j=1}^{n}\lambda_j^1 x_{ij} \le \theta_i x_{io} \qquad i=1,...,m$$

$$\sum_{j=1}^{n}\lambda_j^1 z_{tj} \ge \beta_t z_{to} \qquad t=1,...,p$$

$$\sum_{j=1}^{n}\lambda_j^2 z_{tj} \le \alpha_t z_{to} \qquad t=1,...,m$$

$$\sum_{j=1}^{n}\lambda_j^2 y_{rj} \ge \varphi_r y_{ro} \qquad r=1,...,\mathrm{s}$$

$$\lambda_j^1, \lambda_j^2 \ge 0, \quad j=1,...,n$$

$$0 \le \theta_i \le 1, \quad 0 \le \alpha_t \le 1$$

$$\beta_t \ge 1, \quad \varphi_r \ge 1, \quad \forall i,t,r \qquad (5)$$

In this model, θ_i and α_t are the ratio of the decrease of the input i and the middle of t, respectively, and φ_r and β_t are the ratio of the increase of output r(m) and middle t(m), respectively, for the unit under evaluation.

Also, in this model and in order to make a non-negative combination of observed DMUs, the structural variables $\lambda_j^1(1,...,n)$ and $\lambda_j^2(1,...,n)$ are applied for the stages 1 and 2, respectively. The model is a version of non-radial models for data envelopment analysis.

The optimal value of this model is between 0 and 1. If the optimum value of 1 is obtained, the unit is efficient, otherwise the unit is inefficient.

In this section, mathematical models of NDEA in both Multiple and Envelopment forms are presented for efficiency evaluation. In the next section, an application of these models is presented in an example from the real world.

3. Ranking of Manufactured Cars in Iran

The purpose of this section is to rank cars manufactured by Iranian factories considering the features with the models presented in the previous section. Each car has a set of features that can be used to compare it with other ones to discuss whether it is superior or not. But the point to note here is that it is difficult or impossible to compare because there are so many features. Here, we consider these features as the input, middle and output indicators, which are summarized below.

Input

1. Fuel consumption (lit per 100 kilometer)
2. Price (Rial)

Middle

1. Engine capacity (cc)

Engine capacity is the total capacity of the cylinders. The space hosting each piston to go up and down in the cylinder (the distance between the top and bottom dead points or the cylinder course) is called cylinder capacity. Cylinder capacity multiplied by the number of cylinders is the engine capacity. This capacity is mostly expressed in the unit cc or cubic centimeters and sometimes in liters.

2. Lengths (mm)
3. Widths (mm)
4. Heights (mm)

Output

1. Acceleration (seconds)
2. Speed (kilometer per hours)
3. Satisfaction of Sales process (Satisfaction)

The J. D. Power U. S. Sales Satisfaction Index (SSI) Study provides a comprehensive analysis of the new-vehicle purchase experience from the customer perspective. The study measures the ability of dealerships to manage the sales process, from product presentation and price negotiation to the finance and insurance process and final delivery.

4. Satisfaction of After-sales service satisfaction

The J. D. Power U. S. Customer Service Index (CSI) Study examines customer satisfaction with maintenance and repair service at new-vehicle dealerships. Owners of 1- to 5-year old vehicles are surveyed regarding their most recent dealership service experience for both inwarranty and customer-pay work. The study examines satisfaction in five measures of service experience (containing service initiation, service facility, service advising, vehicle pickup, and service quality).

5. Satisfaction of Initial quality Study satisfaction

The J. D. Power U. S. Initial Quality Study (IQS) serves as the industry benchmark for new-vehicle quality measured at 90 days of ownership and has proven to be an excellent predictor of long term reliability, which may significantly impact new-vehicle purchase decisions. The focus of the study is model-level performance and comparison of individual models to similar models in respective segments, which helps manufacturers worldwide design and produce higher quality vehicles that exceed owners' expectations.

6. Satisfaction of Automotive Performance Execution and Layout.

The J. D. Power U. S. Automotive Performance, Execution and Layout (APEAL) Study examines new-vehicle owners' assessments of the design, content, layout, and performance of their new vehicle after 90 days of ownership. The study data provides manufacturers and suppliers with insight on quality and design satisfaction.

These subdivisions are determined as follows: as for a feature, if the lower means the better performance of the car, it is assumed as the input criterion and in the same vein, if the higher means the better performance, it is assumed as the output criterion. There are also middle criteria for features that can be categorized in both categories, i.e., the lower is better on one hand, and the higher is better on the other. The following is a compilation of the input, middle and output criteria for cars, which is broken down for cars in Table 1.

Table 1. Criteria information for cars under evaluation

Out 6	Out 5	Out 4	Out 3	Out 2	Out 1	Mid 4	Mid 3	Mid 2	Mid 1	In 2	In 1	Auto Model
729	712	761	588	12.03	190	1460	1944	4558	1645	1.00E+09	7.88	Dena
661	693	761	588	12	189	1453	1684	4292	1587	9.00E+08	6.9	Rana
670	731	761	588	10.2	175	1520	1740	4250	1598	2.00E+09	7.3	Tondar 90(IR)
718	709	761	588	14.5	185	1460	1944	4534	1761	1.00E+09	8.6	Samand

Out 6	Out 5	Out 4	Out 3	Out 2	Out 1	Mid 4	Mid 3	Mid 2	Mid 1	In 2	In 1	Auto Model
												Soren
675	698	761	588	14.5	185	1460	190	4502	1761	9.00E+08	8.6	Samand SE
675	700	761	588	12.03	190	1460	1903	4502	1645	9.00E+08	7.8	Samand EF7
663	677	761	588	11.6	185	1432	1652	3822	1587	9.00E+08	6.6	Pegout 206
681	696	761	588	11.4	193	1456	1655	4188	1587	1.00E+09	6.61	Pegout 206 V8
675	686	761	588	12.03	190	1460	1944	4534	1645	1.00E+09	7.88	Samand Soren ELX EF7
704	689	761	588	11	190	1410	1704	4498	1761	1.00E+09	9.5	Pegout Pars
697	690	761	588	11.4	190	1468	1680	3900	1587	2.00E+09	7.1	Pegout 207
686	684	761	588	11	190	1410	1694	4408	1761	9.00E+08	9.1	Pegout 405 GLX
731	678	718	549	11.5	174	1486	1766	4565	1500	1.00E+09	6.7	Ario S300 (M)
700	681	718	549	11.5	172	1486	1766	4565	1590	2.00E+09	6.7	Ario S300(A)
610	599	718	549	14.5	170	1455	1605	3673	1323	6.00E+08	6.9	Pride 111
638	620	718	549	14	170	1455	1605	3935	1323	5.00E+08	7	Pride 131
649	636	718	549	14	170	1455	1605	3952	1323	6.00E+08	7	Pride 132
655	645	718	549	18	200	1484	1641	4105	1503	7.00E+08	6.95	Tiba
668	643	718	549	18	200	1487	1641	3925	1503	7.00E+08	6.7	Tiba2
702	648	718	549	17	180	1484	1645	4215	1503	7.00E+08	6.7	Saina
712	690	718	549	16	160	1524	1688	3989	1503	8.00E+08	7.2	Quick(M)
685	740	725	557	10.2	175	1534	1740	4247	1598	2.00E+09	6.82	Pars Tondar
680	730	725	557	10.2	175	1525	1740	4250	1598	2.00E+09	6.9	Tondar 90(Pars)
739	780	761	588	9.1	192	1566	1778	4122	1200	3.00E+09	5.4	Capture
663	718	725	557	11.5	170	1534	1746	4020	1600	2.00E+09	8.3	Sandero(A)
669	719	725	557	11.5	170	1534	1746	4020	1600	2.00E+09	8.3	Sandero(m)
664	724	718	557	10.5	175	1584	1753	4024	1598	2.00E+09	6.7	Sandero Stepway(M)
729	727	718	549	15	180	1670	1810	4160	1600	2.00E+09	7.2	Changan
712	709	761	588	12.5	183	1528	1760	4351	1600	2.00E+09	7.04	H30cross
663	731	718	557	11.5	170	1584	1753	4024	1598	2.00E+09	8	Sandero Stepway(A)
710	720	718	549	11	180	1482	1703	4390	1500	1.00E+09	6.4	H230(M)
700	719	718	549	11	180	1482	1703	4390	1500	1.00E+09	6.5	H230(A)
691	709	718	549	11.5	170	1482	1703	4170	1500	1.00E+09	6.4	H220(M)
709	697	725	557	11	170	1758	1460	4510	1498	2.00E+09	6.7	H330(A)
702	679	725	557	11	175	1460	1758	4210	1498	2.00E+09	6.7	H320(A)
726	697	727	557	11	170	1460	1758	4210	1498	1.00E+09	6.4	H320(M)
694	729	718	549	10.3	190	1460	1775	4530	2000	3.00E+09	7.7	Cerato (A)
706	729	718	549	10	190	1460	1775	4530	1600	2.00E+09	6.4	Cerato (M)
694	755	761	588	12	185	1695	1810	4500	2400	1.00E+10	9	Vitara (M)
744	744	761	588	15	165	1730	1830	4498	1995	3.00E+09	8.8	Haima S7
710	721	761	588	15	170	1630	1823	4358	1497	2.00E+10	8	Haima S5

Out 6	Out 5	Out 4	Out 3	Out 2	Out 1	Mid 4	Mid 3	Mid 2	Mid 1	In 2	In 1	Auto Model
702	747	761	588	12	175	1695	1810	4500	2400	1.00E+10	9.7	Vitara (A)
724	708	725	557	11	170	1460	1758	4510	1498	1.00E+09	6.4	H330(M)

According to the evaluation criteria specified, the cars are evaluated using the models presented in the paper and ranked based on the results of the car evaluation. The models used here include the Multiple model (4) and the Envelopment model (5). All mathematical programming models in the study will be solved using the Lingo software. Following the implementation of these two models, the results of car evaluation and ranking are presented in Table 2.

Table 2. Evaluation and ranking of cars using the proposed models

Ranked using model 5	Evaluated using model 5	Ranked using model 4	Evaluated using model 4	Auto Model	Ranked using model 5	Evaluated using model 5	Ranked using model 4	Evaluated using model 4	Auto Model
26	0.672	18	0.935	Tondar 90 (Pars)	16	0.720	23	0.915	Dena
1	0.800	1	1	Capture	5	0.783	9	0.979	Rana
31	0.621	30	0.866	Sandero (A)	27	0.669	3	0.651	Tondar 90(IR)
29	0.638	27	0.883	Sandero (m)	18	0.716	25	0.894	Samand Soren
13	0.737	11	0.961	Changan	12	0.743	24	0.898	Samand SE
24	0.691	19	0.934	Sandero Stepway (M)	14	0.736	21	0.930	Samand EF7
22	0.699	17	0.945	H30cross	1	0.800	4	0.995	Pegout 206
30	0.623	29	0.873	Sandero Stepway (A)	1	0.800	6	0.988	Pegout 206 V8
1	0.800	1	1	H230(M)	19	0.705	22	0.918	Samand Soren ELX EF7
8	0.766	4	0.995	H230(A)	25	0.684	31	0.854	Pegout Pars
10	0.760	5	0.994	H220(M)	21	0.701	20	0.933	Pegout 207
1	0.800	13	0.955	H330(A)	17	0.718	28	0.876	Pegout 405 GLX
15	0.722	14	0.953	H320(A)	11	0.759	36	0.695	Ario S300 manual
3	0.794	2	0.999	H320(M)	18	0.716	16	0.949	Ario S300 Automat ic
1	0.800	32	0.853	Cerato (A)	7	0.773	7	0.983	Pride 111
1	0.800	15	0.952	Cerato (M)	2	0.796	2	0.999	Pride 131
20	0.702	34	0.818	Vitara (M)	6	0.778	8	0.981	Pride 132
32	0.601	33	0.844	Haima S7	5	0.783	8	0.981	Tiba
28	0.642	26	0.885	Haima S5	4	0.793	3	0.997	Tiba2

Ranked using model 5	Evaluated using model 5	Ranked using model 4	Evalua-ted using model 4	Auto Model	Ranked using model 5	Evalua-ted using model 5	Ranked using model 4	Evalua-ted using model 4	Auto Model
33	0.531	35	0.766	Vitara (A)	1	0.800	1	1	Saina
1	0.800	2	0.999	H330(M)	9	0.760	10	0.972	Quick
					23	0.694	12	0. 956	Pars Tondar

In Table 2, efficiency and ranking are presented. Based on these results, the cars Saina, Capture, and manual H230 are the top ranks. As you can see from the results of this ranking, 9 cars rank first. It is noteworthy that the cars Saina, Capture, and manual H230 ranked fist by the model (4), are also ranked first by the model (5). Thus, as a conclusion of the ratings of these two models, it can be stated that the Saina, Capture, and manual H 230 are the best rated cars according to the proposed evaluation criteria.

In the above ranking, it can be said that the price is also an influential factor in the ranking because low-priced cars have been high. Then the price input is removed from the criteria and the cars are re-evaluated with results presented in Table 3.

Table 3. Evaluation and ranking of cars using the proposed models after price elimination

Ranked using model 5	Evalua-ted using model 5	Ranked using model 4	Evalua-ted using model 4	Auto Model	Ranked using model 5	Evalua-ted using model 5	Ranked using model 4	Evalua-ted using model 4	Auto Model
26	0.688	22	0.870	Tondar 90(Pars)	19	0.708	27	0.825	Dena
1	0.8	1	1	Capture	8	0.741	13	0.907	Rana
36	0.626	30	0.807	Sandero(A)	29	0.677	23	0.867	Tondar 90(IR)
35	0.627	30	0.807	Sandero (m)	27	0.683	27	0.825	Samand Soren
21	0.702	18	0.896	Changan	28	0.681	28	0.822	Samand SE
24	0.696	9	0.921	Sandero Stepway(M)	28	0.681	24	0.850	Samand EF7
18	0.709	15	0.903	H30cross	6	0.755	12	0.909	Pegout 206
33	0.639	27	0.825	Sandero Stepway(A)	5	0.764	6	0.924	Pegout 206 V8
3	0.771	7	0.924	H230(M)	31	0.662	26	0.847	Samand Soren ELX EF7
12	0.727	11	0.913	H230(A)	34	0.634	33	0.783	Pegout Pars
13	0.723	8	0.922	H220(M)	15	0.717	19	0.884	Pegout 207
7	0.746	14	0.904	H330(A)	32	0.647	12	0.795	Pegout 405 GLX
16	0.715	16	0.900	H320(A)	11	0.731	10	0.918	Ario S300 manual
4	0.769	4	0.932	H320(M)	20	0.704	14	0.904	Ario S300 Automatic
1	0.800	25	0.849	Cerato (A)	21	0.702	20	0.880	Pride 111
1	0.800	10	0.918	Cerato (M)	22	0.700	17	0.899	Pride 131

Ranked using model 5	Evalua-ted using model 5	Ranked using model 4	Evalua-ted using model 4	Auto Model	Ranked using model 5	Evalua-ted using model 5	Ranked using model 4	Evalua-ted using model 4	Auto Model
25	0.689	29	0.818	Vitara (M)	20	0.704	16	0.900	Pride 132
37	0.625	31	0.798	Haima S7	14	0.722	3	0.942	Tiba
30	0.664	21	0.875	Haima S5	10	0.733	2	0.959	Tiba2
38	0.603	34	0.781	Vitara (A)	9	0.739	2	0.959	Saina
2	0.774	5	0.931	H330(M)	17	0.713	7	0.924	Quick
					23	0.697	20	0.880	Pars Tondar

According to the results, the make Capture is ranked first by the model (4) and the makes Capture, automatic Cerato, and manual Cerato are ranked first by the model (5). In both models, the make Capture was first. Thus, the make Capture ranks first, even regardless of price, and can be the best choice in terms of the proposed evaluation criteria. Evaluation of products of the three domestic carmakers Saipa, Iran Khodro and Pars Khodro using models 4 and 5 before and after the elimination of prices is given in Figures 2-7. It is worth noting that the evaluation value using model 5 is always lower than model 4.

Evaluation of Saipa products in Figures 2 and 5 using Multiplexed form before price elimination, Saina and H230 manual cars have efficiency one and using Envelopment form, Saina, H230 manual, Serato manual, and Serato automatics have been efficient. But with the elimination of prices and the use of the Model 4, none of the cars have been efficient, while using Envelopment form Serato manual and Serato automatics are efficient.

In evaluating the performance of Pars Khodro Company's products in Figures 3 and 6 before eliminating the price, only H330 automatics using Envelopment has been efficient. However, after eliminating the price using the 4 and 5 models, no cars were efficient.

In Figures 4 and 7, considering the price in the evaluation of Iran Khodro Company cars using Model 4, Capture has the efficiency equal 1, while eliminating the price again, the same car has been efficient. Before eliminating the price with the 5 model, 206 and 206 V8 are efficient o and after eliminating price Capture is efficient.

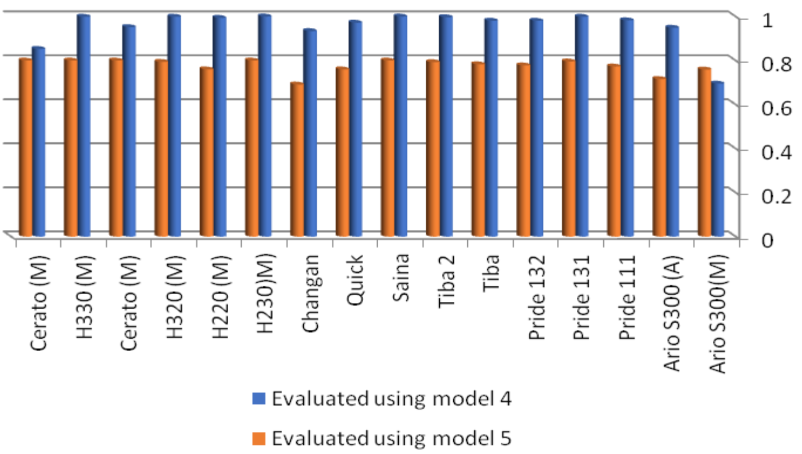

Figure 2. Evaluation of Product of Saipa Company using the proposed models

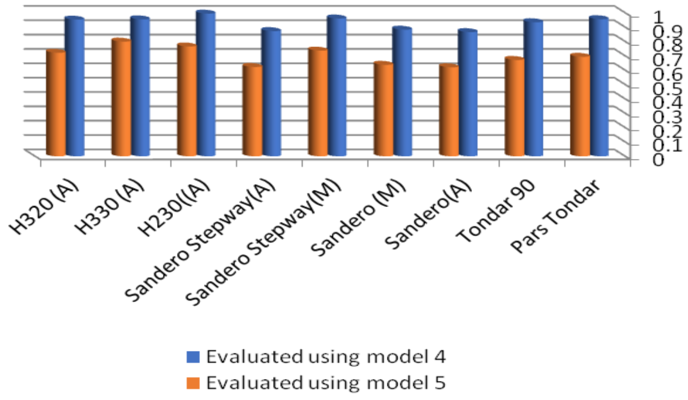

Figure 3. Evaluation of Product of Pars Khodro Company using the proposed models

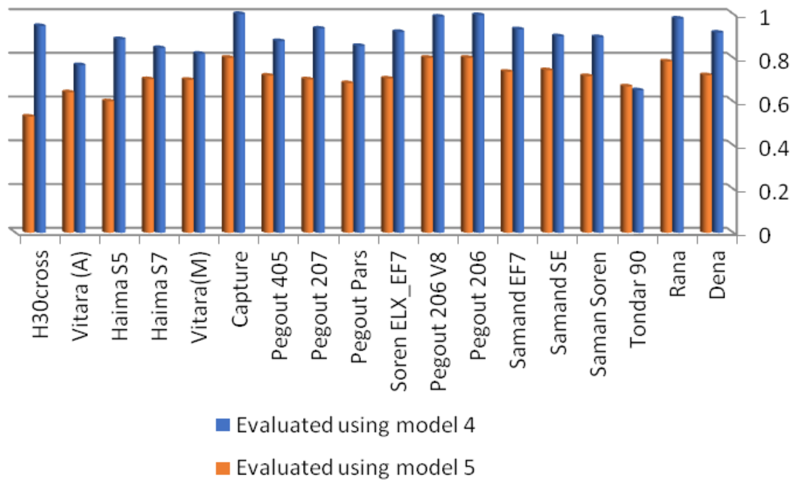

Figure 4. Evaluation of Product of Iran Khodro Company using the proposed models

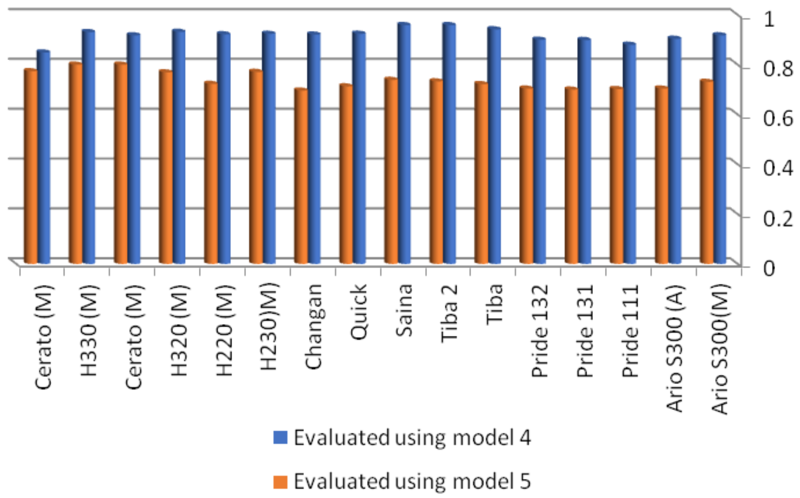

Figure 5. Evaluation of Product of Saipa Company using the proposed models after price elimination

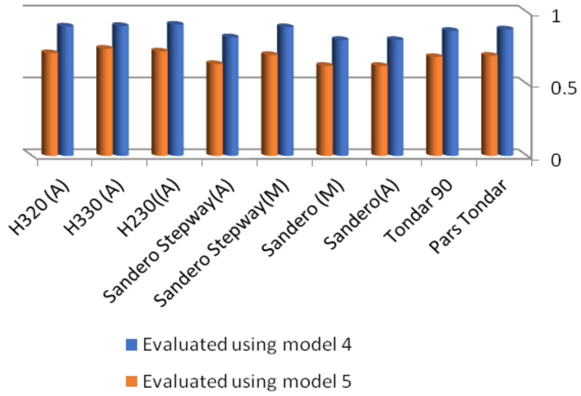

Figure 6. Evaluation of Product of Pars Khodro Company using the proposed models after price elimination

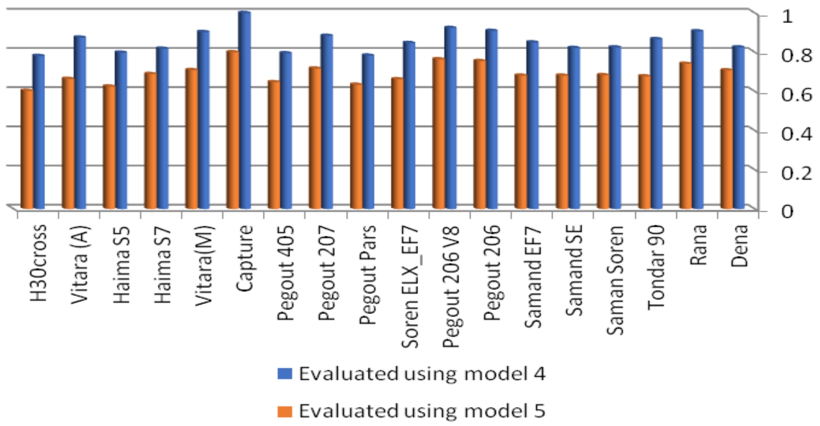

Figure 7. Evaluation of Product of Iran Khodro Company using the proposed models after price elimination

5. Conclusion

Due to the significance of the auto manufacturing industry, the ranking of some cars manufactured in Iranian factories was discussed. The models used for this ranking were mathematical models in Data Envelopment Analysis techniques. In recent years, numerous studies have been presented on a variety of Data Envelopment Analysis models, each of them being designed to address the shortcomings of traditional models. One such type of model that has received much attention recently is the model of Network Data Envelopment Analysis (NDEA). Two models of NDEA are presented in the present paper, and they were used for ranking according to the type of data structure of manufactured cars that was a simple two-stage network. According to the results of the study, 3 out of 43 cars ranked first in the ranking using the models presented. In fact, the three makes Saina, Capture, and manual H 230 rank first. Later, the price index was removed from the evaluation and the cars were re-evaluated using the proposed models. The make Capture was chosen as the best choice in the light of the results obtained. In the paper, two models of NDEA were used for ranking. However, models can also be extended to uncertain environments, such as fuzzy or probabilistic, or use the models presented in another case study for future research.

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