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MULTI-CRITERIA ABC INVENTORY CLASSIFICATION USING RANKING METHODS

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Abstract: *Service facilities store thousands of items as inventory. It is impossible to dedicate the same management efforts and care to every item. Grouping the inventory into specific categories is a common solution for this problem. This paper presents methods for ABC inventory classification via the Data Envelopment Analysis (DEA) and ranking methods according to multi-criteria analysis. A numerical case study illustrates the proposed classification. Each ranking method may generate a different rank so it can be beneficial to use the average ranking method.*
Keywords: *Data Envelopment Analysis (DEA), Ranking Methods, ABC inventory classification, Multi-Criteria Inventory Classification (MCIC)*

INTRODUCTION

Service facilities store thousands of items as inventory. It is impossible to dedicate the same management efforts and care to every item [5]. Grouping the inventory into specific categories is a common solution for this problem. The traditional inventory management for classifying is ABC inventory classification. Items are divided into three groups: group A, B and C. Group A contains 10%-20%, Group B contains 30-40% and Group C contains about 40%-50% of the stock items (see e.g. [9], [14], [11]). However, sorting items only by annual dollar usage may be insufficient to provide a good classification scheme of inventory items ([8], [10]). To overcome this obstacle, inventory items can be sorted into groups by implementing a multi-criteria classification. For example, studies carried out by Ramanathan [11], Hautaniemi and Pirttila [7] and Guvenir and Erel [4] suggested the following criteria: part criticality, lead time, commonality, obsolescence, substitutability, and number of annual requests for the item, scarcity, durability, reparability, order size requirement, stockability, demand distribution and out-of-stock penalty. There are several multiple-criteria ABC classification methods based on the DEA. Applying several classification methods may produce several different ABC classifications for the same inventory. This research proposes to use the average ranking method of Hadad and Hanani [6] to classify the inventory items into ABC groups.

THE RANKING METHODS

There are many different methods to rank DMUs in the DEA context (for a review see [1], [6]). This section presents the ranking methods via DEA that are used in this paper. In our case all the criteria are outputs (without inputs). Therefore the ranking methods were accordingly modified.

THE SUPER-EFFICIENCY MODEL

The most notable of ranking method via the DEA is Andersen and Petersen's super-efficiency model [1]. The modified super-efficiency model that is used in this paper is shown in (1).

$$\begin{aligned} &Max\ S_K = \sum_{r=1}^{S} U_r^K \times Y_{r,K} \\ &S.T. \\ &\sum_{r=1}^{S} U_r^K \times Y_{r,j} \le 1 \qquad j=1,2,...,n \quad \forall j \ne K \qquad (1) \\ &U_r^K \ge 0 \quad r=1,2,..,s \end{aligned}$$

where $Y_{r,j}$ is the value of criterion r of item j, U_r^K is the weight of criterion r that maximizes the score S_K of item K.

THE CROSS-EFFICIENCY MODEL

The cross-efficiency model was developed by Sexton et al. [12]. The cross-efficiency method calculates the efficiency score of each item n times, using the optimal weights of each item. The results of all the DEA cross-efficiency scores can be summarized in cross-efficiency matrix as shown in (2).

$$h_{L,K} = \sum_{r=1}^{S} U_r^K \times Y_{r,L} \quad (2)$$

where $h_{L,K}$ is the score given to item *K* in the DEA run of item *L*. The score of item L is calculated in (3).

$$S_L = \frac{\sum_{k=1}^{n} E_{L,K}}{n} \quad (3)$$

THE DISCRIMINANT ANALYSIS OF RATIO

The discriminant analysis of ratio (DR) was developed by Sinuany-Stern and Friedman [13]. The DR method calculates the score of each item T_j such that ratio of the between-group variance of T, $\left(SS_B(T)\right)$ and the within group variance of T, $\left(SS_W(T)\right)$ will be maximizes as shown in (4).

$$max\ \lambda = max \frac{SS_B(T)}{SS_W(T)} \quad (4)$$

The score T_j is calculated by $T_j = \sum_{r=1}^{S} U_r \times Y_{r,j}$, the average score is calculated by $\overline{T} = \frac{\sum_{j=1}^{n} T_j}{n}$, the average score of the items of group i is calculated by $\overline{T_i} = \frac{\sum_{j \in i} T_j}{n_i}$. The variances are:

$$SS_W(T) = \sum_{i=1}^{3} \left(T_{j \in i} - \overline{T_i}\right)^2,$$

$$SS_B(T) = \sum_{i=1}^{3} n_i \left(\overline{T_i} - \overline{T}\right)^2$$

THE GLOBAL EFFICIENCY

The Global Efficiency (GE) ranking method was developed by Ganley and Cubbin [3]. The criterion of the GE method is to maximize the sum of the scores of all the items as shown in (5).

$$Max\ Z = \sum_{j=1}^{n} \sum_{r=1}^{S} U_r \times Y_{r,j}$$
$$S.T.$$
$$\sum_{r=1}^{S} U_r \times Y_{r,j} \le 1 \qquad j = 1,2,...,n \quad (5)$$
$$U_r \ge 0 \quad r=1,2,..,s$$

THE AVERAGE RANKING

The Average Ranking (AR) method was proposed by Hadad and Hanani [6]. Since each ranking method may generate a different rank, it can be beneficial to use an average ranking. Since the scores of different ranking methods are not based on the same scale, the scores must normalize as shown in (6). $S_{j,i}$ is the score of item *j* according to ranking method *i*.

$$W_{j,i} = \frac{S_{j,i}}{\max_i \left\{S_{j,i}\right\}} \quad \forall i, j \quad (6)$$

The average score of item j is calculated as shown in (7).

$$\overline{S}_j = \frac{\sum_{i=1}^{I} W_{j,i}}{I} \quad j = 1,2,..,n \quad (7)$$

THE CASE STUDY

A garage needs to classify 57 inventory items into ABC groups. The following criteria were defined by the decision makers in the garage: $j-$ item number, Y_1 - annual dollar usage, Y_2- lead time, Y_3 - durability factor. Y_4- the number of car treatments that needs the item, Y_5- critical factor (shortage). Table 1 presents the normalized values of each criterion for all the items. See Table 1 at the end of the paper.

Table 2 presents the scores for all the items according to each ranging method, the ABC classification by the ranking methods and the average scores and rank. Table 3 presents the scores, ranking and the group classification according to the average ranking method. .

CONCLUSIONS

This paper proposes a method that can help mangers to identify the most significant items and thus enables them to allocate effectively their managerial efforts and care. Since each ranking method has its own objective function, it is the prerogative the decision-maker to select the appropriate ranking method from his/her point of view. In case when several ranking methods are used (such as when the decision-makers are of different opinions as to the method to be used), the decision maker can use of the proposed average ranking.

***Table 1*:** The data (normalized values)

j	Y_1	Y_2	Y_3	Y_4	Y_5	j	Y_1	Y_2	Y_3	Y_4	Y_5
A1	0.0564	0.3839	0.2760	0.9426	0.6668	A30	0.4458	1	0.9401	0.5402	0.9686
A2	0.0723	0.5546	0.6270	0.3149	0.9066	A31	0.1665	0.6328	0.1787	0.6633	0.4471
A3	0.0477	0.4788	0.4193	0.7778	0.8095	A32	0.0291	0.5801	0.3299	0.7565	0.1576
A4	0.0531	0.6875	0.8468	0.5791	0.6007	A33	0.0737	0.1099	0.8849	0.7391	0.4219
A5	0.0080	0.6958	0.0361	0.0257	0.5066	A34	0.0534	0.8418	0.6411	0.3527	0.4354
A6	0.0302	0.0417	0.8741	0.3654	0.6087	A35	0.0699	0.2528	0.0232	0.4183	0.3308
A7	0.1432	0.9503	0.5568	0.8697	0.2835	A36	0.0790	0.6293	0.4181	0.1555	0.0170
A8	0.0686	0.2062	0.9741	0.7968	0.4485	A37	0.0440	0.3224	0.7886	0.1574	0.0606
A9	1	0.2364	0.1112	0.3411	0.1722	A38	0.0713	0.9158	0.7381	0.7835	0.2797

A10	0.0190	0.3363	0.2045	0.0241	0.3106	A39	0.0726	0.1783	0.9092	0.8696	0.3721
A11	0.0490	0.2383	0.7600	0.2222	1	A40	0.0598	0.6966	0.7299	0.2409	0.7665
A12	0.0148	0.5923	0.7377	0.1463	0.1160	A41	0.0600	0.1231	0.1946	0.7686	0.4219
A13	0.1172	0.0351	0.4240	0.0200	0.5929	A42	0.0808	0.0362	0.3878	0.7646	0.3630
A14	0.0564	0.9816	0.4445	0.9105	0.4049	A43	0.0358	0.3354	0.8583	0.1332	0.4823
A15	0.6050	0.7364	0.3359	0.1525	0.6388	A44	0.0149	0.8140	0.9890	0.9064	0.3884
A16	0.0760	0.3589	0.3290	0.4519	0.3455	A45	0.0771	0.0221	0.5746	0.5656	0.6125
A17	0.0529	0.4451	0.5089	0.4125	0.3885	A46	0.0802	0.5842	0.9628	0.0653	0.7802
A18	0.1696	0.4152	0.1097	0.9533	0.9013	A47	0.1551	0.8914	0.7087	0.8993	0.8610
A19	0.0331	0.0189	0.3134	0.7216	0.9195	A48	0.1824	0.6398	0.1718	0.3045	0.6761
A20	0.0871	0.4342	0.4917	0.7659	0.7325	A49	0.1528	0.3388	0.2344	0.9439	0.8857
A21	0.0681	0.6282	0.7215	0.6981	0.9697	A50	0.1606	0.9764	0.4944	0.3707	0.1116
A22	0.0173	0.9166	0.8862	0.9354	0.7044	A51	0.1620	0.3309	0.6621	0.2023	0.6843
A23	0.1016	0.0185	0.6789	0.7756	0.0459	A52	0.1630	0.8029	1	0.3979	0.5564
A24	0.0668	0.4802	0.9857	0.3042	0.9833	A53	0.0576	0.4744	0.7394	0.9834	0.8853
A25	0.0688	0.7765	0.4221	0.7325	0.2645	A54	0.0444	0.6802	0.2943	0.8249	0.8028
A26	0.0823	0.1154	0.1773	0.3661	0.1722	A55	0.0863	1.0000	0.8118	0.4554	0.9766
A27	0.1640	0.2282	0.2824	1	0.3388	A56	0.0295	0.2373	0.6313	0.7845	0.2651
A28	0.014975	0.1876	0.8487	0.9060	0.6166	A57	0.0409	0.6783	0.7158	0.6832	0.8325
A29	0.0429	0.8816	0.4391	0.5762	0.1693						

Table 2: **Group classification by the ranking methods**

Item	SE			CE			DAR			GE		
	Score	Rank	Group	Score	Rank	Group	Score	Rank	Group	Score	Rank	Group
A1	0.9134	23	C	0.6508	23	C	2.7162	22	C	0.8102	18	B
A2	0.858	29	C	0.6043	26	C	2.705	23	C	0.5091	42	C
A3	0.8636	28	C	0.677	21	B	2.9041	18	B	0.7443	24	C
A4	0.8551	30	C	0.713	14	B	3.0512	14	B	0.7495	23	C
A5	0.5999	50	C	0.2747	55	C	1.4585	51	C	0.0702	57	C
A6	0.8164	32	C	0.5069	40	C	2.0441	41	C	0.5765	38	C
A7	0.9694	13	B	0.7464	10	B	3.1465	10	B	0.9084	9	A
A8	0.943	16	B	0.6958	17	B	2.7258	21	B	0.9327	8	A
A9	1.5309	1	A	0.4435	48	C	1.4796	50	C	0.8641	12	B
A10	0.3086	57	C	0.2028	57	C	0.976	57	C	0.1139	56	C
A11	0.9156	22	C	0.5558	34	C	2.435	29	C	0.4674	46	C
A12	0.6881	46	C	0.3936	50	C	1.7061	49	C	0.3737	51	C
A13	0.5325	53	C	0.2783	54	C	1.1903	55	C	0.2382	55	C
A14	1.0095	7	A	0.7477	9	A	3.2299	9	A	0.8543	15	B
A15	0.9265	17	B	0.5576	32	C	2.3752	32	C	0.6066	36	C
A16	0.488	54	C	0.4143	49	C	1.7409	48	C	0.4873	43	C
A17	0.5402	52	C	0.4688	45	C	1.9959	43	C	0.5093	41	C
A18	0.9848	8	A	0.693	19	B	2.9309	16	B	0.8362	16	B
A19	0.8852	24	C	0.5561	33	C	2.3147	34	C	0.6507	31	C
A20	0.8114	34	C	0.6733	22	C	2.8344	20	B	0.7789	21	B
A21	0.9835	9	A	0.7961	7	A	3.4474	7	A	0.8086	19	B
A22	1.052	4	A	0.9282	2	A	3.9202	3	A	1	1	A
A23	0.7707	38	C	0.4915	42	C	1.7616	47	C	0.8231	17	B
A24	0.9643	15	B	0.6934	18	B	3.0228	15	B	0.6158	35	C
A25	0.7905	36	C	0.6067	25	C	2.5841	27	C	0.7198	27	C
A26	0.3845	56	C	0.2572	56	C	1.0099	56	C	0.3691	52	C
A27	0.9821	11	B	0.5911	28	C	2.2914	35	C	0.9004	10	B
A28	0.9159	21	B	0.7253	12	B	2.8962	19	B	0.9408	7	A
A29	0.8139	33	C	0.5496	35	C	2.3987	31	C	0.6021	37	C
A30	1.371	2	A	0.9484	1	A	4.0514	1	A	1	1	A
A31	0.7363	43	C	0.5495	36	C	2.3529	33	C	0.649	33	C
A32	0.7402	41	C	0.5197	38	C	2.1605	38	C	0.6742	30	C
A33	0.8548	31	C	0.6272	24	C	2.4273	30	C	0.8624	13	B
A34	0.7782	37	C	0.5731	30	C	2.5571	28	C	0.5249	40	C
A35	0.4282	55	C	0.297	53	C	1.2695	54	C	0.3566	53	C
A36	0.5525	51	C	0.3134	52	C	1.3806	53	C	0.3109	54	C
A37	0.7126	45	C	0.349	51	C	1.4035	52	C	0.405	50	C
A38	0.9234	19	B	0.7392	11	B	3.1253	11	B	0.865	11	B
A39	0.9247	18	B	0.6837	20	B	2.6425	25	C	0.9614	6	A
A40	0.7521	40	C	0.5998	27	C	2.7049	24	C	0.4846	44	C
A41	0.7287	44	C	0.4599	46	C	1.8328	46	C	0.6494	32	C
A42	0.7385	42	C	0.4816	43	C	1.8485	45	C	0.7175	28	C
A43	0.7989	35	C	0.4521	47	C	1.9284	44	C	0.4185	48	C

Item	SE			CE			DAR			GE		
	Score	Rank	Group	Score	Rank	Group	Score	Rank	Group	Score	Rank	Group
A44	1.043	5	A	0.84	5	A	3.4977	6	A	1	1	A
A45	0.6547	48	C	0.5088	39	C	2.0292	42	C	0.6446	34	C
A46	0.9231	20	B	0.5801	29	C	2.5869	26	C	0.4472	47	C
A47	1.0563	3	A	0.9138	3	A	3.9206	2	A	1	1	A
A48	0.6484	49	C	0.4725	44	C	2.1558	39	C	0.4127	49	C
A49	0.9698	12	B	0.6992	16	B	2.9201	17	B	0.8579	14	B
A50	0.8638	27	C	0.52	37	C	2.2816	36	C	0.5464	39	C
A51	0.6592	47	C	0.496	41	C	2.1186	40	C	0.4808	45	C
A52	0.9822	10	B	0.7231	13	B	3.0927	12	B	0.7394	26	C
A53	1.0386	6	A	0.852	4	A	3.5551	5	A	1	1	A
A54	0.8829	26	C	0.7011	15	B	3.0748	13	B	0.7403	25	C
A55	0.9685	14	B	0.8128	6	A	3.6653	4	A	0.6915	29	C
A56	0.7645	39	C	0.5609	31	C	2.2004	37	C	0.785	20	B
A57	0.8844	25	C	0.7637	8	A	3.3124	8	A	0.7784	22	C

***Table 3*:** Group classification by average ranking

Item	Score	Rank	Group	Item	Score	Rank	Group
A1	0.6909	20	B	A30	0.9739	1	A
A2	0.5936	31	C	A31	0.5725	34	C
A3	0.6848	21	B	A32	0.5597	39	C
A4	0.7032	19	B	A33	0.6703	26	C
A5	0.2779	56	C	A34	0.5672	37	C
A6	0.5372	42	C	A35	0.3157	53	C
A7	0.7763	7	A	A36	0.3358	52	C
A8	0.7388	13	B	A37	0.3962	51	C
A9	0.6742	25	C	A38	0.7548	10	B
A10	0.1926	57	C	A39	0.7346	15	B
A11	0.5631	38	C	A40	0.5690	36	C
A12	0.4148	50	C	A41	0.5157	44	C
A13	0.2933	54	C	A42	0.5410	41	C
A14	0.7748	8	A	A43	0.4733	46	C
A15	0.5965	30	C	A44	0.8576	5	A
A16	0.4182	49	C	A45	0.5274	43	C
A17	0.4623	48	C	A46	0.5751	33	C
A18	0.7334	16	B	A47	0.9053	3	A
A19	0.5967	29	C	A48	0.4666	47	C
A20	0.6796	24	C	A49	0.7373	14	B
A21	0.7853	6	A	A50	0.5555	40	C
A22	0.9084	2	A	A51	0.4893	45	C
A23	0.5699	35	C	A52	0.7267	17	B
A24	0.6807	23	C	A53	0.8636	4	A
A25	0.6284	27	C	A54	0.7038	18	B
A26	0.2852	55	C	A55	0.7715	9	A
A27	0.6827	22	C	A56	0.6047	28	C
A28	0.7547	11	B	A57	0.7447	12	B
A29	0.5763	32	C				