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An Integrated ABC-FUCOM Model for Product Classification

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ABSTRACT

Grouping products to determine their impact on business is a necessity. Therefore, in this paper, the integration of ABC analysis and the full consistency method (FUCOM) for determining a group of products is carried out. FUCOM is used to obtain the weighting coefficients for a group of products of Gorenje appliances. The research was conducted in the "Mepromex" shopping mall. The FUCOM method is applied to determine the values of three criteria: unit price, quantity, and annual procurement value. These criteria play a major role in the final sorting of products in this type of analysis. Additionally, a comparative analysis (i.e. single-criterion ABC analysis) is performed for each criterion separately.

1. Introduction

Inventory represents the quantity of goods that is stored for continuous supply in time and space closer to or further from production or personal consumption. Inventory management is one of the key elements of business logistics. The main task is to make inventory as small as possible, but always sufficient to satisfy the requirements of customers and consumers. Too much inventory results in high storage costs, and too little inventory implies numerous problems, difficulties, and adverse consequences in production, trade, and distribution [1]. It is necessary to constantly maintain an optimal amount of inventory in distribution and production to ensure the continuity of sales or production.

The FUCOM method, developed by Pamučar et al. [2], represents an innovative approach to determining the weights of criteria in multi-criteria decision-making models. This method facilitates the precise determination of weighting coefficients for elements that are compared to each other within a certain hierarchy. What is particularly significant is its ability to provide model validation through error calculation for the resulting weight vectors, while maintaining consistency across comparisons. The advantage of this method is significant since it reduces subjectivity in a decision-making process, considering that the weighting coefficients decisively affect the final solutions in so-

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me methods [2]. In the context of multi-criteria models, defining relative weights of criteria is often a challenging task due to the inherent subjectivity of decision-makers.

ABC analysis is a specific inventory management system that starts from the fact that, in terms of monitoring and control, only a few items deserve attention, which, however, have a significant share in the total values or inventory costs. These are items that are classified in group A (extremely important products), while group B (moderately important products) and C (relatively unimportant products) consist of items, the share of which increases by type and decreases by value. In other words, the most attention is given to group A, less to group B, and least to group C [3]. ABC analysis is closely related to the Pareto principle, which states that there is often an inverse relationship between the percentage of items in each group and the significance of the groups. In the case of ABC analysis, the following rules for determining priorities are applied, and they can be shown based on the volume of the production program [4-6]:

- i. *Group A* – 80% of the production program (priority level I);
- ii. *Group B* – 15% of the production program (priority level II);
- iii. *Group C* – 5% of the production program (priority level III).

Regarding this paper, all the necessary data were obtained from the "Mepromex" shopping mall. ABC analysis was performed using the FUCOM method (which was used to obtain the weighting coefficients) for the stock sale product group - Gorenje appliances. This group consists of a total of 226 products. The paper aims to provide support analysis to managers of a company in order to make more reliable decisions and give more attention to the most important products.

2. Methodology

To write the review paper, it was first necessary to collect all the necessary data, then obtain weighting coefficients using the FUCOM method to perform an ABC analysis based on multi-criteria decision-making (MCDM), and, lastly, perform a comparative analysis (single-criterion ABC analysis). Further, in Figure 1, a short research procedure is given.

2.1. FUCOM Method

The FUCOM method is applied to obtain the weighting coefficients of criteria through the following procedure [2,7-10]:

Step 1 – First, the ranking of the criteria from a predefined set of evaluation criteria $C = \{C_1, C_2, \dots, C_n\}$ is performed:

$$C_{j(1)} > C_{j(2)} > \dots > C_{j(k)}, \quad (1)$$

where k is a rank of the criterion considered.

Step 2 – The ranked criteria are mutually compared and comparative importance $(\varphi_{k/(k+1)}) = 1, 2, \dots, n$, is identified:

$$\Phi = (\varphi_{1/2}, \varphi_{2/3}, \dots, \varphi_{k/(k+1)}), \quad (2)$$

where k is a rank of the evaluation criteria.

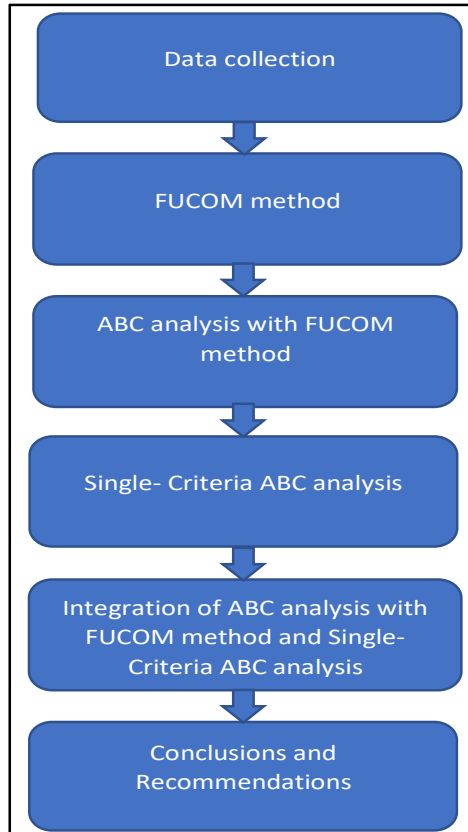


Fig. 1. Research procedure.

Step 3 – The final values of the weighting coefficients of the evaluation criteria $(w_1, w_2, \dots, w_n)^T$ are computed. The final values should meet two conditions:

- i. The ratio of the weighting coefficients is equivalent to the comparative importance among the criteria considered $(\varphi_{k/(k+1)})$, as determined in **Step 2**, more specifically, that the following condition is met:

$$\frac{w_k}{w_{k+1}} = \varphi_{k/(k+1)}. \tag{3}$$

- ii. The condition of mathematical transitivity, i.e. that $\varphi_{k/(k+1)} \otimes \varphi_{k+1/(k+2)} = \varphi_{k/(k+2)}$ should be met by the final values of the weighting coefficients. Since $\varphi_{k/(k+1)} = \frac{w_k}{w_{k+1}}$ and $\varphi_{(k+1)/(k+2)} = \frac{w_{k+1}}{w_{k+2}}$, then $\frac{w_k}{w_{k+1}} \otimes \frac{w_{k+1}}{w_{k+2}} = \frac{w_k}{w_{k+2}}$. So, the final values of the weighting coefficients of the evaluation criteria should fulfill the second condition, which is as follows:

$$\frac{w_k}{w_{k+2}} = \varphi_{\frac{k}{k+1}} \otimes \varphi_{\frac{k+1}{k+2}}. \tag{4}$$

Based on the above, a final model for determining the final values of the weighting coefficients of the evaluation criteria can be created.

min χ

s.t.

$$\left| \frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)} \right| = \chi, \forall j$$

$$\left| \frac{w_{j(k)}}{w_{j(k+2)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \right| = \chi, \forall j \tag{5}$$

$$\sum_{j=1}^n w_j = 1,$$

$$w_j \geq 0, \forall j$$

2.2. ABC Analysis

ABC analysis is focused on identifying the products of the greatest benefit [11-14]. The condition that should be met by the cost percentage share of individual product groups about the total procurement costs is given by:

$$A = 40 - 80\%, \quad B = 15 - 40\%, \quad C = 5 - 20\%. \tag{6}$$

The condition that should be met by the percentage share of the number of individual product groups out of the total number of all product types is given by:

$$A = 5 - 25\%, \quad B = 20 - 40\%, \quad C = 40 - 75\%. \tag{7}$$

The third condition defines the relation of the number of products by groups $A < B < C$.

3. ABC Analysis with the FUCOM Method

Further in the paper, Table 1 shows the sale of Gorenje appliances for 12 months. It consists of a total of 226 products with their code, quantity calculated, procurement value, and unit price. Then, a sum is made for all three criteria.

Table 1
 Criteria values and their sums for all categories

No.	Code	Product name	Unit measure	Quantity sold	Procurement value	Unit price
1	6361138	KETTLE K 17 WII	PCS	456	10,001.26	21.93
2	6205240	KETTLE K 17 S	PCS	258	8476.30	32.85
3	6970747	AIR CONDITIONER HISENSE EXPERT SMART 12 INVERTER	PCS	108	62,704.63	580.60
4	6970640	AIR CONDITIONER HISENSE 12K TV35VD1	PCS	96	45,313.22	472.01
5	6724155	GORENJE BUILT-IN JUMP SET	PCS	80	46,494.95	581.19
...
222	6201189	GORENJE REFRIGERATOR NRK6191ES4	PCS	1	596.84	596.84
223	6132549	TOASTER T 800 ORA W	PCS	1	54.86	54.86
224	6042218	GORENJE DRYER DE8B	PCS	1	528.53	528.53
225	6039634	GORENJE REFRIGERATOR ORK 192 CR	PCS	1	632.50	632.50
226	6035744	GORENJE FREEZER F6171CW	PCS	1	544.38	544.38
Σ				2150	459,798.35	74,653.39

After calculating the sums for each criterion separately, the share of each product is calculated individually and the weighting coefficients obtained using the FUCOM method are multiplied for each share separately. The obtained weighting coefficients are given in Table 2.

Table 2

Values of weighting coefficients obtained using the FUCOM method

Criteria	C ₂	C ₃	C ₁
WC _j (k)	0.510	0.268	0.222

The share of all products and the multiplication of the obtained weighting coefficients with the shares are shown in Table 3.

Table 3

Criteria values and their sums for all categories

Code	Share of Q	Share of APV	Share of UP	MCDM-Q	MCDM-APV	MCDM-UP
6361138	21.21%	2.18%	0.03%	4.71%	0.58%	0.01%
6205240	12.00%	1.84%	0.04%	2.66%	0.49%	0.02%
6970747	5.02%	13.64%	0.78%	1.12%	3.65%	0.40%
6970640	4.47%	9.86%	0.63%	0.99%	2.64%	0.32%
6724155	3.72%	10.11%	0.78%	0.83%	2.71%	0.40%
...
6201189	0.05%	0.13%	0.80%	0.01%	0.03%	0.41%
6132549	0.05%	0.01%	0.07%	0.01%	0.00%	0.04%
6042218	0.05%	0.11%	0.71%	0.01%	0.03%	0.36%
6039634	0.05%	0.14%	0.85%	0.01%	0.04%	0.43%
6035744	0.05%	0.12%	0.73%	0.01%	0.03%	0.37%

When the weighting of the criteria is completed, the next task that needs to be done is to obtain the final percentage value for each product individually, by adding MCDM-Q, MCDM-APV, and MCDM-UP. Sorting the final percentage values from the highest to the lowest and obtaining their cumulative is the next step. All calculations are given in Table 4.

Table 4

Percentage values, cumulative, and products ranked into groups

Final	Final	Cumulative	Group
5.31%	5.31%	5.31%	A
3.18%	5.17%	10.47%	A
5.17%	3.95%	14.43%	A
3.95%	3.93%	18.36%	A
3.93%	3.18%	21.54%	A
...
0.79%	0.61%	43.15%	B
0.76%	0.60%	43.75%	B
0.29%	0.58%	44.34%	B
1.02%	0.58%	44.92%	B
1.28%	0.57%	45.49%	B
...
0.46%	0.33%	82.05%	C
0.30%	0.33%	82.38%	C
0.04%	0.33%	82.71%	C
0.10%	0.32%	83.03%	C
0.44%	0.32%	83.36%	C

The last step that is done in this part is the ABC analysis; i.e. classifying products into groups A, B, and C. The classification is made based on a previously calculated cumulative. The products classified into groups A, B, and C are also given in Table 4.

4. Single-Criterion ABC analysis

After the ABC analysis based on multi-criteria decision-making was calculated using the FUCOM method, the single-criterion ABC analysis was also computed, and it was carried out separately for each specified criterion (quantity, annual procurement value, unit price) for the same product group – stock sale of Gorenje appliances. The quantities of all products were added in the first step ΣQ_j . The sum of all quantities was 2510, the sum of all procurement values was 459,798.35, and the sum of all unit prices was 74,653.39. The next step was to determine the share of each product separately in the total amount of products, in the total UP, and in the total APV. Ranking from the highest to the lowest value, then calculating the cumulative, and classifying the products into groups A, B, and C was the last that was completed. The single-criterion ABC analysis for all three criteria is shown separately in Table 5, Table 6, and Table 7.

Table 5
 Criteria values and their sums for all categories

No.	Code	Product name	Unit measure	Quantity sold	Share of Q	Ranking	Cumulative	Group
1	6361138	KETTLE K 17 WII	PCS	456	21.21%	21.21%	21.21%	A
2	6205240	KETTLE K 17 S	PCS	258	12.00%	12.00%	33.21%	A
3	6970747	AIR CONDITIONER HISENSE EXSPERT SMART 12 INVERTER	PCS	108	5.02%	5.02%	38.23%	A
...
4	6970640	AIR CONDITIONER HISENSE 12K TV35VD1	PCS	96	4.47%	4.47%	42.70%	B
5	6724155	GORENJE BUILT-IN JUMP SET	PCS	80	3.72%	3.72%	46.42%	B
6	6703542	GORENJE HOOD TH60E3X	PCS	59	2.74%	2.74%	49.16%	B
7	6231905	GORENJE BOILER TG 50 NG	PCS	55	2.56%	2.56%	51.72%	B
8	6590078	FOIL WELDER VS 120 W	PCS	45	2.09%	2.09%	53.81%	B
...
55	6532444	MICROWAVE OVEN MO 17E 1W	PCS	7	0.33%	0.33%	81.67%	C
56	6396166	GORENJE REFRIGERATOR RF 6275 W	PCS	7	0.33%	0.33%	82.00%	C
57	6359658	MICROWAVE OVEN MIMO 20 DEII	PCS	7	0.33%	0.33%	82.33%	C
58	6966000	GORENJE STOVE E 6110 WB	PCS	6	0.28%	0.28%	82.60%	C
59	6855596	GORENJE FREEZER FH 401 CW	PCS	6	0.28%	0.28%	82.88%	C

Table 6

ABC analysis for the procurement value criterion of the Gorenje product group

No.	Code	Product name	Unit measure	Procurement value	Share of APV	Ranking	Cumulative	Group	
1	6361138	KETTLE K 17 WII	PCS	10,001.26	2.18%	13.64%	13.64%	A	
2	6205240	KETTLE K 17 S	PCS	8476.30	1.84%	10.11%	23.75%	A	
3	6970747	SMART 12 INVERTER	PCS	62,704.63	13.64%	9.86%	33.60%	A	
4	6970640	HISENSE 12K TV35VD1	PCS	45,313.22	9.86%	2.87%	36.47%	A	
5	6724155	JUMP SET	PCS	46,494.95	10.11%	2.18%	38.65%	A	
...	
8	6590078	WELDER VS 120 W	PCS	4430.49	0.96%	1.84%	44.43%	B	
9	6231906	BOILER TG 80 NG	PCS	5667.76	1.23%	1.69%	46.13%	B	
10	6754212	MIXER M 360 CW	PCS	887.86	0.19%	1.58%	47.70%	B	
11	6526635	WP 60S3	PCS	8848.21	1.92%	1.50%	49.21%	B	
12	6875777	FRIDGE RKI 4182 E1	PCS	13,191.78	2.87%	1.49%	50.69%	B	
...	
222	6201189	NRK6191ES4	PCS	596.84	0.13%	0.01%	99.98%	C	
223	6132549	T 800 ORA W	PCS	54.86	0.01%	0.01%	99.98%	C	
224	6042218	DRYER DE8B	PCS	528.53	0.11%	0.01%	99.99%	C	
225	6039634	ORK 192 CR	PCS	632.50	0.14%	0.01%	99.99%	C	
226	6035744	FREEZER F6171CW	PCS	544.38	0.12%	0.01%	100.00%	C	
				459,798.35					

Table 7

ABC analysis for the unit price criterion of the Gorenje product group

No.	Code	Product name	Unit measure	Unit price	Share of UP	Ranking	Cumulative	Group	
1	6361138	KETTLE K 17 WII	PCS	21.93	0.03%	1.57%	1.57%	A	
2	6205240	KETTLE K 17 S	PCS	32.85	0.04%	1.43%	3.00%	A	
3	6970747	EXSPERT SMART 12 INVERTER	PCS	580.60	0.78%	1.40%	4.40%	A	
4	6970640	HISENSE 12K TV35VD1	PCS	472.01	0.63%	1.39%	5.79%	A	
5	6724155	BUILT-IN JUMP SET	PCS	581.19	0.78%	1.24%	7.03%	A	
...	
46	6875599	REFRIGERATOR R4141PW	PCS	334.96	0.45%	0.71%	40.45%	B	
47	6596366	JUICER JC 805 EII	PCS	96.63	0.13%	0.71%	41.16%	B	
48	6537975	VC 2421 ECW	PCS	159.86	0.21%	0.71%	41.86%	B	
49	6357377	EC 640 SF IN PL	PCS	309.97	0.42%	0.70%	42.57%	B	
50	6970388	DISHWASHER GV520E15	PCS	468.49	0.63%	0.70%	43.27%	B	
...	
222	6201189	NRK6191ES4	PCS	596.84	0.80%	0.03%	99.90%	C	
223	6132549	TOASTER T 800 ORA W	PCS	54.86	0.07%	0.03%	99.94%	C	
224	6042218	GORENJE DRYER DE8B	PCS	528.53	0.71%	0.03%	99.96%	C	
225	6039634	ORK 192 CR	PCS	632.50	0.85%	0.02%	99.98%	C	
226	6035744	FREEZER F6171CW	PCS	544.38	0.73%	0.02%	100.00%	C	
				74,653.39					

5. Conclusions

In the paper, the ABC analysis based on the weights of the criteria using the FUCOM method was thoroughly presented. In addition, a comparative analysis including a single-criterion ABC analysis was performed. All data were collected in the "Mepromex" shopping mall for the section of household appliances, i.e. stock sale - Gorenje appliances. After calculating the ABC analysis based

on MCDM for the production group of Gorenje appliances, group A consists of 30 products and these are the products that are the most important and should be given the most attention, group B consists of 88 products and these are products that are treated the same as other products in group A, but with certain corrections, and these are less important products. Group C is a group with 108 products, and these are less important products. Regarding the percentage share, the product with the highest percentage share is P2 (kettle k 17 wii) with 5.13%, and the product with the lowest percentage share is P135 (hair dryer hd 122 b) with 0.03%.

The results obtained after the calculation of the single-criterion ABC analysis are: observing the tables, the product found in group A in all analyses is the product P3 (air conditioner hisense expert smart 12 inverter). The products that are in all analyses in group B are:

- i. P38 (Gorenje washing machine wnhvb60ses);
- ii. P44 (Gorenje oven bo6737e02x).

The products that are only found in group B in the single-criterion ABC analysis are:

- i. P29 (Gorenje washing machine wnhvb72sds);
- ii. P31 (Gorenje washing machine wnei74bs);
- iii. P33 (microwave oven mo17e1s).

The products that are in group C in both analyses are:

- i. P55 (microwave oven mo 17e 1w);
- ii. P57 (microwave oven mmo 20 deii);
- iii. P61 (toaster sm 701 gcw).

This paper shows how ABC analysis can be adapted to suit specific needs and contexts, providing a valuable tool for inventory management and decision-making related to product procurement priorities. Guidelines for future research can be manifested through the implementation of such a model for other different products in the company to make a full support analysis.

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