Applied Multiple Criteria Inventory Classification for General Spare Parts: A case Study in Cement Industry in Thailand

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Abstract

Since the conventional ABC inventory classification has major drawback that it takes consider only single criterion as the annual spending to classify inventory items. This leads to incorrect classification of inventory. As a matter of fact, there are many criteria involved in the decision making of inventory classification. This study proposes a multi-criteria inventory classification (MCIC) model to categorize the general spare part inventories based on ABC classification fundamental. A cement company in Thailand is used as a case study. The inventory classification criteria composed of unit cost, quantity usage per annual, annual spending, lead-time, number of potential suppliers and product life cycle. In this study Shannon's Entropy method is employed to calculate the object weights of inventory classification criteria. Subsequently, TOPSIS is used to sort and classify the spare part items. In addition, a comparison between the conventional ABC classification and the proposed MCIC model was performed to demonstrate the differences between the two approaches. The findings of this study could help logistics managers responsible for inventory management make rational decisions on inventory classification.

Keywords
Multiple Criteria Inventory Classification, Shannon's Entropy, TOPSIS and Inventory Management

1. Introduction
Regarding the Inventory Management, ABC classification is applying the technique to develop a model for clarify inventory items that is significant and reflect to the amount of inventory cost. It is also affected to management and operation way to deal with classify item in the business. The research has approved plenty of method ABC inventory classification. For example, using Shannon's Entropy and TOPSIS algorithm for multiple criteria ABC inventory classification.

ABC Inventory Management always used ABC analysis base on Pareto Principle 80:20 portion practices and clarify classification of inventory in three group. Classified from A to C. in term of group "A" high important, middle important item are in group "B" and the rest for low important are in group "C"

Generally, ABC analysis is a criterion for a yearly spending of inventory item. But to consider on price prior unit, minimum order quantity, lead-time, holding cost, critically parts, effect to production line when machine breakdown, obsolete parts, shelf-life, demand forecast, period of replacement, available stock, yearly consumption, mode of transportation for delivery and penalty cost and all of criteria that may affect to the item classification. The inventory should classify on multi-criteria to manage it properly and cover with all scenario. There are three step criteria starting with choosing the criteria, choose of alternatives one and weight scoring with expected to the criteria. In the research that we assign weight scoring and use subjective judgments or artificial complex techniques. However, the artificial complex techniques (AI) cannot classify and create more complexity to the employee and the subjective judgments disposed to take a favorable view of events. To cope with weight scoring and complex techniques, we would propose multi-criteria classification for classify inventory item and implement inventory policy infallibly.

1.1 Objectives

Applied Shannon's Entropy and TOPSIS Method for classified inventory group by using 6 criteria which are Unit Cost (Thai Bath), Usage (Unit), Annual spending (Thai Bath), Lead Time (Day), No. of potential suppliers (Unit) and Product Lifecycle (month)

2. Literature Review

To construe a result of evaluation, the most favor inventory control system is ABC analysis because the method is only reflecting on the amount of usage for ranking and organize inventory items which is inadequate. For example, the additional number of MCDM methods appear to support ABC classification and a top trend as the result of their ability to collect the criteria inventory management such as lead-time, unit cost, parts important, ability for maintenance, holding cost, order consumption and etc. (Kabir and Sumi 2013).

In Business Industry, the inventory classification method is clarified in ABC analysis. These methods used to determine the spare parts item and for Service categories. (Molenaers A 2011). The method of classification supportive industry to simplify the way of working for inventory management. The main proposed of ABC classification is to identify the inventory items or any product that they keep in the warehouse and separate into the classes, which are class A (its high important items), Class B (middle important items) and the rest for class C (lowest or unimportant items) (Hatefi S 2014).

To classify a spare part by using a simple mathematic, we have two major criteria which are logistic and maintenance using in the research. Spare parts could be identified into three categories A, B, and C - Were important, middle important and unimportant respectively. Then we will implement the matching strategy for each type of inventory classification (Antosz and Ratnayake 2016).

According to the theory of (F. Y. Partovi and W. E. Hopton 1994), it shown that the inventory that had 3 or more complex criteria should implement the multi-criteria inventory method while multi-variate techniques help grouping and identify items conforming to sameness. The case study of (Y. Chen 2008) supports the theory of multi-criteria ABC classification by using a weighted Euclidean distances and quadratic optimization program to seek for optimal threshold and preferences respectively. The case study shown improvement of multiple classification problem because the number of misclassification and diminish of outliers is dramatically reduce.

Organized and combined model it including a distance of multi criteria versus scheme base on the practice of TOPSIS to develop the group of ABC Classifications. (Bhattacharya et al. 2007). They consideration and implement more three criteria important which are price per unit, quantity, aging of items, cost of sorting and lead-time. Analysis with Stock keeping unit and applied in Pharmaceutical business in India. The researcher tested the model of inventory and ensure the performance by using ANOVA method. Considering of lead time, cost, consumption rate, Risk Priority Number and sensitivity. The environment and safety measurement to make a decision to classify the spar part by implement the TOPSIS manner. The easiest way to classify inventory is ABC method that simply use one method, cost of yearly disbursement of spare parts (Shahin and Gholami 2014).

TOPSIS is appropriate for a general situation in the business that always had a complex situation as a consequent of a simple and flexible which can apply for all situation and also integrated with technique of ABC classification. As a result, MCIC issue was fixed efficiency due to the algorithm and weight distance required for decision making. TOPSIS is used to rank the items for the classification of multi-criteria inventory. Finally, comparison with Shannon's Entropy techniques was also performed in this work.

3. Methods

This research, we applied Shannon's entropy and TOPSIS to integrated between subjective weight of 6 important criteria in the Multiple Criteria Inventory Classification process for General Spare Parts A Case Study in Cement Industry in Thailand. Shannon's entropy is appropriate concept in the complex field of information. This theory can use a measure of vary items. It able to calculate the weight on ranking item and we make a decision for each item then ranking it.

Step 1: Normalize decision matrices.

$$P_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \qquad (1)$$

Step 2: Calculate the entropy in each column.

$$E_i = \frac{\sum_{j=1}^{n} P_{ij} \cdot \ln P_{ij}}{\ln n} \qquad (2)$$

Step 3: Calculate the vector of Normalize Weight.

$$W_i = \frac{1 - E_i}{\sum_{i=1}^{m} (1 - E_i)} \qquad (3)$$

The steps of TOPSIS algorithm can be expressed as follows:

Step 1: Set ranking criteria for linguistic variables with relevant criteria. and the measurement scale as in Table 2.3 and used to calculate the weight of the assessment criteria. Shannon's entropy was used in this study to determine the threshold weight

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} \end{array} \qquad (4)$$

Step 2: Create a fuzzy matrix for alternatives based on a group of experts. with alternative m and n criteria.
Step 3: Normalize decision matrices and consider each criterion as a benefit or cost.

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m \times n} \qquad (5)$$

Clarify: $i = 1, 2, 3, 4, 5, \ldots, m$ และ $j = 1, 2, 3, 4, 5, \ldots, n$

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u_{ij}}{u_j^*}\right) \text{and } u_j^* = \max u_{ij} \text{ (benefit)} \qquad (6)$$

$$\tilde{r}_{ij} = \left(\frac{l_j^*}{u_{ij}}, \frac{l_j^*}{m_{ij}}, \frac{l_j^*}{l_{ij}}\right) \text{and } l_j^* = \max l_{ij} \text{ (cost)} \qquad (7)$$

Step 4: Normalize decision matrices

$$\tilde{r}_{ij} = \frac{l + 2m + u}{4} \tag{8}$$

Step 5: Weighted Standard Decision Matrix

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{m \times n} \tag{9}$$

Clarify: $i = 1, 2, 3, \ldots, m$ and $j = 1, 2, 3, \ldots, n$

and $$\tilde{v}_{ij} = \tilde{r}_{ij} \times w_j \tag{10}$$

Step 6: Determine the positive ideal (positive idea solution: A^+) and the negative ideal (Negative idea solution: A^-) as the following equations.

$$A^+ = \left\{v_1^+, \ldots, v_n^+\right\},\ v_i^+ = \left\{\max\left(v_{ij}\right) if\ j \in J; \min\left(v_{ij}\right) if\ j \in J'\right\}, J = 1,2,3,4,5,\ldots n \tag{11}$$

$$A^- = \left\{v_1^-, \ldots, v_n^-\right\},\ v_i^- = \left\{\min\left(v_{ij}\right) if\ j \in J; \max\left(v_{ij}\right) if\ j \in J'\right\}, J = 1,2,3,4,5,\ldots n \tag{12}$$

Step 7: Calculate the distance $d_i^+\left(A_i, A^+\right)$ and $d_i^-\left(A_i, A^-\right)$ of each option. from the positive idea solution (A^+) and the negative idea solution (A^-) as the following equation

$$d_i^+\left(A_i, A^+\right) = \left\{\sum_{j=1}^{n}\left(v_{ij} - v_{ij}^+\right)^2\right\}^{\frac{1}{2}},\ i = 1, \ldots, m \tag{13}$$

$$d_i^-\left(A_i, A^-\right) = \left\{\sum_{j=1}^{n}\left(v_{ij} - v_{ij}^-\right)^2\right\}^{\frac{1}{2}},\ i = 1, \ldots, m \tag{14}$$

Step 8: Calculate the proximity coefficient $\left(CC_i\right)$ of each choice as the following equation

$$CC_i = \frac{\sum_{j=1}^{n} d_i^-\left(A_i, A^-\right)}{\sum_{j=1}^{n} d_i^-\left(A_i, A^-\right) + \sum_{j=1}^{n} d_i^+\left(A_i, A^+\right)},\ i = 1, \ldots, m \quad C_i \in (0,1) \tag{15}$$

4. Data Collection

Gathering the information for 60 items of general spare parts from SAP System and separate the detail with 6 criteria in Cement Industry in Thailand.

The first steps are to finalize criteria for inventory classification. For this classification, the criteria considered are Unit Cost (Thai Bath), Usage (Unit), Annual spending (Thai Bath), Lead Time (Day), No. of potential suppliers (Unit) and Product Lifecycle (month).

5. Results and Discussion

Previously multi-criteria inventory classification models are complex thing due to the weights assigning to a different factor with complex techniques that are laborious to study for inventory staff who had a little experience and knowledge. The most efficient model of proposed model is a multi-criteria inventory classification in the view of the fact that it the most uncomplicate for perceive of inventory staff of the company particularly for General spare parts from Cement Industry in Thailand.

This weight assignment is not precise classification of items on these weights. But proposed model takes into account all weights equally because its importance of all classifying factor and part in inventory management and control for company operations in production line.

Table 1. Criteria of inventory items and transformed measures from Shannon's Entropy

Item	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Normalize					
	Price (THB)	Quantity (Unit)	Amount (THB)	Leadtime (Day)	No. of potential suppliers	Lifecycle Stage (month)	F1	F2	F3	F4	F5	F6
1	1,539.00	460	1,029,591.00	15	4	12	0.002	0.011	0.109	0.033	0.02	0.013
2	3,142.86	905	814,000.00	15	4	12	0.003	0.023	0.086	0.033	0.02	0.013
3	2,909.09	890	349,090.91	15	4	12	0.003	0.022	0.037	0.033	0.02	0.013
4	5,550.00	875	327,450.00	7	4	12	0.006	0.022	0.035	0.015	0.02	0.013
5	10,676.92	868	309,630.77	7	2	12	0.011	0.022	0.033	0.015	0.01	0.013
6	40,525.71	861	283,680.00	7	2	18	0.042	0.021	0.03	0.015	0.01	0.019
7	3,895.00	854	276,545.00	7	4	6	0.004	0.021	0.029	0.015	0.02	0.006
8	39,285.71	847	275,000.00	7	2	24	0.041	0.021	0.029	0.015	0.01	0.025
9	2,808.00	840	263,952.00	7	4	12	0.003	0.021	0.028	0.015	0.02	0.013
10	2,250.00	833	229,500.00	15	4	12	0.002	0.021	0.024	0.033	0.02	0.013
11	6,000.00	818	216,000.00	7	4	6	0.006	0.02	0.023	0.015	0.02	0.006
12	68,500.00	811	205,500.00	7	3	6	0.071	0.02	0.022	0.015	0.015	0.006
13	195,000.00	804	195,000.00	7	2	36	0.202	0.02	0.021	0.015	0.01	0.038
14	1,539.00	797	180,063.00	7	4	6	0.002	0.02	0.019	0.015	0.02	0.006
15	2,568.57	790	172,094.29	15	4	12	0.003	0.02	0.018	0.033	0.02	0.013
16	42,000.00	775	168,000.00	7	1	24	0.044	0.019	0.018	0.015	0.005	0.025
17	7,600.00	768	159,600.00	7	4	12	0.008	0.019	0.017	0.015	0.02	0.013
18	6,000.00	761	156,000.00	7	4	12	0.006	0.019	0.017	0.015	0.02	0.013
19	2,300.00	754	151,800.00	15	4	12	0.002	0.019	0.016	0.033	0.02	0.013
20	13,604.00	739	149,644.00	5	4	12	0.014	0.018	0.016	0.011	0.02	0.013
21	14,875.00	734	148,750.00	7	4	12	0.015	0.018	0.016	0.015	0.02	0.013
22	5,115.00	727	148,335.00	7	4	6	0.005	0.018	0.016	0.015	0.02	0.006
23	4,862.00	720	145,860.00	5	2	6	0.005	0.018	0.015	0.011	0.01	0.006
24	14,000.00	715	140,000.00	7	2	6	0.015	0.018	0.015	0.015	0.01	0.006
25	5,115.00	708	127,875.00	7	4	6	0.005	0.018	0.014	0.015	0.02	0.006
26	2,650.00	701	127,200.00	5	4	12	0.003	0.017	0.013	0.011	0.02	0.013
27	1,680.00	696	126,000.00	7	4	6	0.002	0.017	0.013	0.015	0.02	0.006
28	2,511.00	689	125,550.00	7	4	6	0.003	0.017	0.013	0.015	0.02	0.006
29	120,000.00	682	120,000.00	5	2	60	0.124	0.017	0.013	0.011	0.01	0.064
30	4,350.00	677	117,450.00	7	2	18	0.005	0.017	0.012	0.015	0.01	0.019
31	4,337.50	670	108,437.50	7	2	12	0.004	0.017	0.011	0.015	0.01	0.013
32	5,450.00	663	103,550.00	7	2	12	0.006	0.016	0.011	0.015	0.01	0.013
33	49,000.00	656	98,000.00	7	2	36	0.051	0.016	0.01	0.015	0.01	0.038
34	24,150.00	649	96,600.00	7	2	60	0.025	0.016	0.01	0.015	0.01	0.064
35	30,166.67	642	90,500.00	7	2	12	0.031	0.016	0.01	0.015	0.01	0.013

36	4,385.71	635	87,714.29	7	4	12	0.005	0.016	0.009	0.015	0.02	0.013
37	3,500.00	628	84,000.00	15	4	12	0.004	0.016	0.009	0.033	0.02	0.013
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.	.	.	.	.	.	.	.	.	.	.	.	.
60	17,500.00	465	52,500.00	5	2	24	0.018	0.012	0.006	0.011	0.01	0.025

Table 2. Weight results for Multicriteria Shannon's and TOPSIS

Item	**Multicriteria Shannon's and TOPSIS**
I1	0.2165
I2	0.1323
I3	0.0856
I4	0.2615
I5	0.1781
I6	0.2070
I7	0.2025
I8	0.1275
I9	0.1469
I10	0.4812
I11	0.1442
I12	0.1227
I13	0.1347
I14	0.1323
I15	0.1294
I16	0.1521
I17	0.1227
I18	0.3870
I19	0.0935
I20	0.1494
.	.
.	.
.	.
I60	0.1194

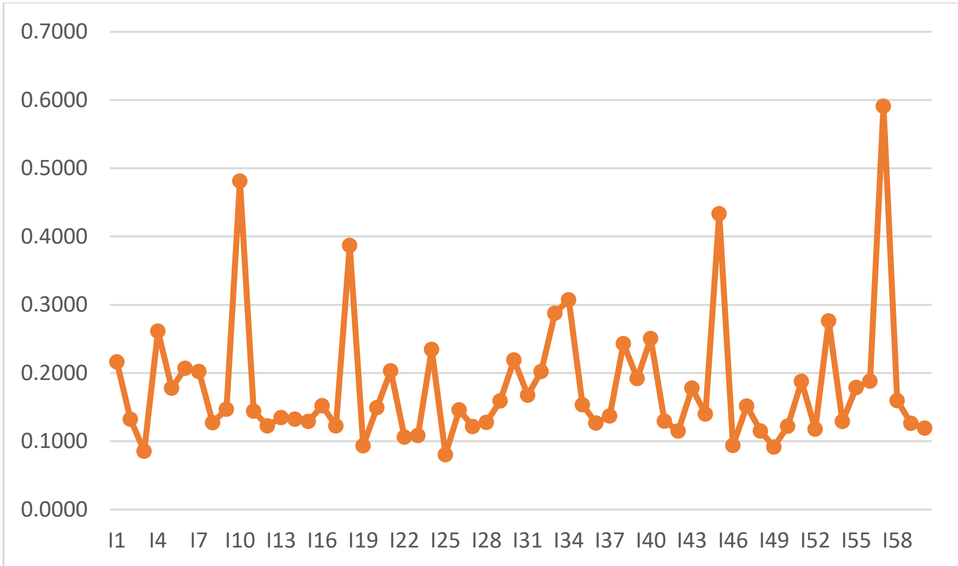

Figure 1. The weighting for Shannon's Entropy and TOPSIS

Table 3. Base on 6 Criteria and ranking item from 2 methods comparison with classification group.

Item	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Ranking		Classification Group	
	Price (THB)	Quantity (Unit)	Amount (THB)	Leadtime (Day)	No. of potential suppliers	Lifecycle Stage (month)	Traditional ABC Analysis	TOPSIS	Traditional ABC Analysis	Multi Criteria
1	1,539.00	460	1,029,591.00	15	4	12	1	3	A	A
2	3,142.86	905	814,000.00	15	4	12	2	4	A	A
3	2,909.09	890	349,090.91	15	4	12	3	9	A	A
4	5,550.00	875	327,450.00	7	4	12	4	16	A	A
5	10,676.92	868	309,630.77	7	2	12	5	21	A	A
6	40,525.71	861	283,680.00	7	2	18	6	11	A	A
7	3,895.00	854	276,545.00	7	4	6	7	22	A	A
8	39,285.71	847	275,000.00	7	2	24	8	10	A	A
9	2,808.00	840	263,952.00	7	4	12	9	23	A	A
10	2,250.00	833	229,500.00	15	4	12	10	12	A	A
11	6,000.00	818	216,000.00	7	4	6	11	26	A	A
12	68,500.00	811	205,500.00	7	3	6	12	7	A	A
13	195,000.00	804	195,000.00	7	2	36	13	1	A	A
14	1,539.00	797	180,063.00	7	4	6	14	32	A	A
15	2,568.57	790	172,094.29	15	4	12	15	14	A	A
16	42,000.00	775	168,000.00	7	1	24	16	13	A	A
17	7,600.00	768	159,600.00	7	4	12	17	30	A	A
18	6,000.00	761	156,000.00	7	4	12	18	31	A	A
19	2,300.00	754	151,800.00	15	4	12	19	17	A	A
20	13,604.00	739	149,644.00	5	4	12	20	33	A	A
21	14,875.00	734	148,750.00	7	4	12	21	27	A	A
22	5,115.00	727	148,335.00	7	4	6	22	35	A	A

23	4,862.00	720	145,860.00	5	2	6	23	59	A	B
24	14,000.00	715	140,000.00	7	2	6	24	54	A	B
25	5,115.00	708	127,875.00	7	4	6	25	38	A	A
26	2,650.00	701	127,200.00	5	4	12	26	42	A	A
27	1,680.00	696	126,000.00	7	4	6	27	39	A	A
28	2,511.00	689	125,550.00	7	4	6	28	40	A	A
29	120,000.00	682	120,000.00	5	2	60	29	2	A	A
30	4,350.00	677	117,450.00	7	2	18	30	52	A	B
31	4,337.50	670	108,437.50	7	2	12	31	56	A	B
32	5,450.00	663	103,550.00	7	2	12	32	57	A	B
33	49,000.00	656	98,000.00	7	2	36	33	8	A	A
34	24,150.00	649	96,600.00	7	2	60	34	5	B	A
35	30,166.67	642	90,500.00	7	2	12	35	34	B	A
36	4,385.71	635	87,714.29	7	4	12	36	41	B	A
37	3,500.00	628	84,000.00	15	4	12	37	18	B	A
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
60	17,500.00	465	52,500.00	5	2	24	60	36	C	A

6. Conclusion

This research, calculate weight normalized base upon Shannon's Entropy and TOPSIS to proposed the items of inventory classification from important criteria. The one model of inventory classification came from Shannon's Entropy it makes simplify and easy to use in Cement Industry Business and in deep to general spare parts with the simple way of inventory management.

The Shannon's method helps to standardize the complexity of key indication of each SKU so that we can prioritize it at the same criteria and we ranking the score of each item. The scheme of MCIC model, indication is given to classify inventory on multiple factors.

Compare the result of classification group between Shannon's Entropy/TOPSIS as this method for multi criteria and Traditional ABC Analysis, 28 items out of the 60 items are classified difference. In term of classification group, A, 21 of 28 classified in Multi criteria and 5 of 28 classified in Traditional ABC Analysis. For group B, 5 of 28 classified in multi criteria and 15 of 28 classified in Traditional ABC Analysis. The rest in group C, 2 of 28 classified in multi criteria and 8 of 28 classified in Traditional ABC Analysis

The discrepancy in classification come from the two comparisons resulted from the weight scoring method between Shannon's entropy and TOPSIS. The weight result combine with scoring result will help classify ABC inventory classification.

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