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Flexible ABC Inventory Classification

Rathanaksambath Ly and Morrakot Raweewan

School of Management Technology, Sirindhorn International Institute of Technology, Thammasat University, Pathumthani 12120, Thailand

Abstract

ABC inventory classification is a well-known approach to assign inventory item into A, B, and C groups based on their sales and usage volume. This helps inventory management become more efficient. Behind its advantage, it usually shows some problems with an inventory budget and warehouse space because the ABC assignment of SKUs are mad e without an inventory budget and space available involved. In this paper, the ABC group under restricted of an inventory budget and warehouse space to maximize the profit with optimal service level is presented. We establish this proposed model to enhance the existing ABC approach to be more applicable in real life, which has the limited inventory budget and warehouse space.

Keywords: ABC Inventory Classification; Inventory Management

Corresponding Author
Rathanaksambath Ly
morrakot@siit.tu.ac.th

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INTRODUCTION

Agro-industry products need a very careful inventory management to maintain quality of the products. ABC inventory classification is a well-known approach to assign inventory items into A, B, and C groups. Each group has an individual policy to manage products appropriately. This classification uses the Pareto principle. The traditional ABC approach is simple to understand and is used by inventory managers and supervisors. SKUs are classified based on their annual use values and sales.

A small number of items may contribute to the large proportion of volume, while a medium group may have a moderate proportion of volume. A large number of items may account for a small proportion of volume [9]. This often shows that a small proportion of the SKUs accounted for the majority of company's sales and revenue. This has led to the 80-20 rule. The top 20% of inventory is grouped as the A class and the next 30% and 50% are grouped as class B and class C, respectively [5]. Each class already has a selected service level. For example, 95%, 75%, and 50% are set for class A, B, and C, respectively. Implementers usually use the traditional ABC grouping scheme in following approach to manage inventory. First, SKUs are classified based on their sale volume. Second, inventory policies are decided for each group. Finally, the inventory manager needs to verify with financial department to ensure that inventory policy is feasible within the provided inventory budget and available warehouse space. There are some disadvantages of ABC inventory classification. (a) There are no clear approaches to determine the service level in the literature Teunter et al. [12]. (b) Since the inventory grouping decision is made separately from the available budget and warehouse space, there is no guarantee that set service level is feasible.

The study presented in this paper improves the ABC inventory classification to be more flexible. First, SKUs are grouped by annual use value the same as ABC approach. Then, the model simultaneously chooses the optimal service level for each group within available inventory budget and warehouse space. These inputs are made to maximize the total revenue. We use generated data to implement in traditional ABC and this proposed model. We compare the solution from this model and traditional ABC model on total 1,000 SKUs.

This paper is organized as follows. Section 2 provides the related research literature and emphasizes contribution on this work. Section 3 discusses our proposed model. Section 4 the computational result is presented. Finally, Section 5 summarizes and concludes this work.

LITERATURE REVIEW

There are many research studies focus on inventory classification exist in the literature. However, most of them are conducted to extend from single criteria to multi-criteria classification by using difference model and approach. There are no existed studies has conducted to find the optimal service level on traditional ABC. Some of them focus only on inventory grouping alone, while other researchers have included inventory control such as policy and performance.

The classic method of making group as ABC based on a volume/cost metric [9] have been used to extend by many researchers to consider multi criterions. The first multi-criteria classification using the joint criteria matrix was conducted by considering lead times, substitutability, critical factors, commonality and reparability [5]. Partovi and Burton [10] used the analytic hierarchy process to propose a systematic approach to quantify the priority of SKUs.

Some researchers treated inventory classification as an optimization problem. They use a weight linear program based on Data Envelopment Analysis (DEA) Ramanathan

[11] and Zhou and Fan [14], and extended by Hadi-Vencheh [7] and Chen [3]. Guvenir and Erel [6] developed the genetic algorithm with metaheuristic. The other metaheuristic called particle swarm optimization has been developed by Tsai and Yeh [13].

The other type of inventory classification addressed the relationship between classification and control decisions. Those studies were conducted to minimize the total inventory cost calculated by the summation of holding cost and ordering cost. Crouch and Oglesby [4] conducted the research to minimize the total inventory cost. In their model, the holding cost of all SKUs was assumed the same over the time period. However, it seems difficult to apply in real life. The study of minimizing the cost by considering the product of demand rate and holding cost rate (or PHDC) was researched by Chakravarty [2]. That research used their dynamic programming algorithm which was improved by PDHC to illustrate that the optimal grouping can be obtained.

Millstein, Yang, and Li [8] recently developed an optimization model to find the optimal number of inventory group and service level for each group under considering the available inventory budget and management overhead cost. The overhead cost of their study was set to be constant. The objective function is set to maximize net profit. They assigned SKUs in more than three groups with specified service level (fill rate) for each group to maximize the total profit. It still has problem to apply in real life because the thousands of SKUs need to be reassigned again which led to many unexpected problems and more expenses. This study is conducted to maximize profit which focuses on single criteria. The inventory budget and warehouse space is simultaneously included in this model which is different from all literature studies.

MODEL DEVELOPMENT

This study still uses the approach of ABC inventory classification based on annual use value. After that, the target service level for each group will be assigned by our model written in CPLEX. The optimized service level which considered together with inventory budget and warehouse space is built to maximize the profit. It has been formulated as mixed integer linear program (MILP).

Notation:

NA, NB, & NC: Number of inventory items in group A, B, & C (SKUs)

MA, MB, & MC: maximum number of inventory group A, B, & C

d_{ia}, d_{ib}, & d_{ic}: mean of monthly demand of SKU ia, ib, & ic = 1,...,NA, NB, & NC

□$_{ia}$, □$_{ib}$, & □$_{ic}$: standard deviation of monthly demand of SKU ia, ib, & ic = 1,...,NA,NB, & NC

l_{ia}, l_{ib}, & l_{ic} lead time of SKU ia, ib, & ic = 1,...,NA, NB, & NC

g_{ia}, g_{ib}, & g_{ic}: net profit per unit of SKU ia, ib, & ic = 1,...,NA, NB, & NC

c_{ia}, c_{ib}, & c_{ic}: inventory holding cost per unit SKU ia, ib, & ic = 1,...,NA, NB, & NC

z_{ja}, z_{jb}, & z_{jc}: z-value associated with group ja, jb, & jc = 1,...,MA,MB, &MC

s_{ja}, s_{jb}, & s_{jc}: service level associated with group ja, jb, & jc: 1,...,MA, MB, & MC

B: planned inventory spending budget

IP_{ia}, IP_{ib}, & IP'_{ic}: maximum number of item i can store with 1 pallet ia, ib, & ic = 1,...,NA, NB, &NC

ATS: Total number of pallet can store in provided space

Decision variable:

yA_{ja}, yB_{jb}, & yC_{jc} = 1 if inventory group ja, jb, and jc is selected, and 0 otherwise. for ja, jb, & jc=1,...,MA, MB, & MC

xA_{iaja}, xB_{ibjb}, & xC_{icjc} = 1: if SKU ia, ib, and ic is assigned to group ja, jb, and jc for ia, ib, & ic =1,...,NA, NB, & NC; and ja, jb, & jc=1,...,MA, MB, &, MC

v_{ia}, v_{ib}, & v_{ic} ≥ 0: inventory level of SKU ia, ib, & ic= 1,...,NA, NB, & NC

Objective function

Maximize

$$\sum_{ia=1}^{NA}\sum_{ja=1}^{MA} g_{ia}d_{ia}s_{ja}xA_{iaja} + \sum_{ib=1}^{NB}\sum_{jb=1}^{MB} g_{ib}d_{ib}s_{jb}xB_{ibjb} + \sum_{ic=1}^{NC}\sum_{jc=1}^{MC} g_{ic}d_{ic}s_{jc}xC_{icjc} \tag{1}$$

Constraints

$$\sum_{ja=1}^{MA} xA_{iaja} = 1, \quad \forall ia = 1, .., NA \tag{2}$$

$$\sum_{jb=1}^{MB} xB_{ibjb} = 1, \quad \forall ib = 1, .., NB \tag{3}$$

$$\sum_{jc=1}^{MC} xC_{icjc} = 1, \quad \forall ic = 1, .., NC \tag{4}$$

$$\sum_{ia=1}^{NA} xA_{iaja} = NAy_{ja}, \quad \forall ja = 1, \ldots, MA \tag{5}$$

$$\sum_{ib=1}^{NB} xB_{ibjb} = NBy_{jb}, \quad \forall jb = 1, \ldots, MB \tag{6}$$

$$\sum_{ic=1}^{NC} xC_{icjc} = NCy_{jc}, \quad \forall jc = 1, \ldots, MC \tag{7}$$

$$v_{ia} = \sum_{ja=1}^{MA} d_{ia} l_{ia} xA_{iaja} + \sum_{ja=1}^{MA} z_{ja} \sigma_{ia} \sqrt{l_{ia} x_{iaja}}, \forall ia = 1, \ldots, NA \tag{8}$$

$$v_{ib} = \sum_{jb=1}^{MB} d_{ib} l_{ib} xB_{ibjb} + \sum_{jb=1}^{MB} z_{jb} \sigma_{ib} \sqrt{l_{ib} x_{ibjb}}, \forall ib = 1, \ldots, NB \tag{9}$$

$$v_{ic} = \sum_{jc=1}^{MC} d_{ic} l_{ic} xC_{icjc} + \sum_{jc=1}^{MC} z_{jc} \sigma_{ic} \sqrt{l_{ic} x_{icjc}}, \forall ic = 1, \ldots, NC \tag{10}$$

$$\sum_{ia=1}^{NA} C_{ia} v_{ia} + \sum_{ib=1}^{NB} c_{ib} v_{ib} + \sum_{ic=1}^{NC} c_{ic} v_{ic} \le B \tag{11}$$

$$\sum_{ia=1}^{NA} \frac{v_{ia}}{IP_{ia}} + \sum_{ib=1}^{NB} \frac{v_{ib}}{IP_{ib}} + \sum_{ic=1}^{NC} \frac{v_{ic}}{IP_{ic}} \le \text{ATS} \tag{12}$$

$$v_{ia} \geq 0, \quad \forall ia = 1, .., NA \tag{13}$$

$$v_{ib} \geq 0, \quad \forall ib = 1, .., NB \tag{14}$$

$$v_{ic} \geq 0, \quad \forall ic = 1, .., NC \tag{15}$$

$$xA_{iaja} = [0, 1], \quad \forall ia = 1, .., NA; \forall ja = 1, \ldots, MA \tag{16}$$

$$xB_{ibjb} = [0, 1], \quad \forall ib = 1, .., NB; \forall jb = 1, \ldots, MB \tag{17}$$

$$xB_{icjc} = [0, 1], \quad \forall ic = 1, .., NC; \forall jc = 1, \ldots, MC \tag{18}$$

$$yA_{ja},\ yB_{jb},\ \text{and}\ yC_{jc} = [0, 1], \quad \forall ja = 1, \ldots, MA;\ \forall jb = 1, \ldots, MB,\ \forall jc = 1, \ldots, MC \tag{19}$$

The objective function (1) is built to maximize the total profit, calculated by the summation of the gross profit generated by groups A, B, and C. The service level (s_{ja}, s_{jb}, & s_{jc}) is treated as a fill rate to calculate the satisfied demand by inventory level. The fill rate has also been used by other researchers such as Teunter et al. [12] and Millstein et al. [8]. Constraints (2), (3), and (4) force the model to assign an SKU into one group. Constraints (5), (6), and (7) enforce that only an open group is allowed to be assigned an SKU. Constraints (8), (9), and (10) calculate the inventory level of SKUs by the summation of demand during the lead time and safety stock (in the case of uncertain demand and certain lead time) [1]. Constraint (11) ensures that the inventory budget is higher than the total inventory holding cost. Constraint (12) ensures that the total space required to store all SKUs do not exceed the available warehouse space. Constraints (13) through (19) identify the domains of decision variables.

COMPUTATIONAL RESULT

In the calculations, the potential 108 different service levels from 1% to 99% (with the increment of 1%), include 9 service levels from 99.1% to 99.9% (with the increment of 0.1%), which are chosen to consider for ABC service levels. We solved our MILP model by the branch and cut method in CPLEX 12.3 on a laptop PC with 2.7 GHz CPU speed and 8 GB memory. CPLEX spent about 1 minute and a half to find the optimal solution (and prove optimality).

We implement the model in three scenarios. Scenario 1: we set the inventory budget 104,000 USD and warehouse space 500 pallets. Scenario 2: the inventory budget and warehouse is set higher with 118,000 USD and 520 pallets space to see how our model flexibly assigns the service level. Scenario 3: the proposed model uses within the tight inventory budget 100,000 USD and warehouse space of 430 pallets..

We set these three scenarios to see how flexible this model is in different situations.

We compare traditional ABC classification (with 95%, 75%, and 50% for service level of group A, B, and C, respectively) with the proposed optimal ABC classification (ABC*). Results are following

In Scenario 1, by changing the traditional ABC service level to optimal service level, which found by the proposed MILP model, its profit improves 2.9% from 1,641,071 USD to 1,688,725 USD. The service for ABC group is changed from 95%, 75%, & 50% to the

Table 1: Profit in USD comparison between the traditional ABC and the optimal ABC in three scenarios.

	Scenario1	Scenario2	Scenario3
ABC	1,641,071	1,641,071	infeasible
ABC*	1,688,725	1,843,463	1,584,417

optimal service level 92%, 89%, & 82%, respectively. Profit found by our model and ABC traditional is shown in Table 1]below.

In Scenario 2, inventory budget and warehouse space increase. The model improves profit up to 12.33% compared to the traditional ABC by changing the service level to 99.3%, 99.1%, and 99% for group A, B, and C, respectively. Though we increase the inventory budget and space, the ABC method still keeps the same service level which provides no profit improvement. However, this model finds optimal service level to maximize profit.

The ABC approach will be infeasible if the inventory budget and warehouse space are lower than numbers provided in Scenario 1. In Scenario 3, we decreased inventory budget to 100,000 and 430 pallet space available to see how flexible our model is. The profit found by changing the service level to 89%, 85%, & 1% of ABC group is 1,584,417 USD. The model assigned group C to have only 1% of service level. It seems inapplicable in real life; however, to maximize the profit within a limited budget and warehouse space, it is an optimal solution.

We perform the additional experiment by control the service level of group C to have more than 10% of service level on our proposed model. The reason for controlling the service level is to show that our model is capable of altering condition, based on the changing of inventory policy. The result shows that the proposed model is flexible in real life with inventory policy in different situations. The net profit provides by the proposed model is 1,573,348 USD by changing the service level 86%, 83%, and 69% for group A, B, and C, respectively. It is slightly smaller than the previous experiment by only 0.69%. This proposed model produce more benefit when there are more inventory budget and bigger warehouse space while the traditional ABC cannot improve profit. There is no guarantee that traditional ABC is feasible with rule 95%, 75%, and 50% of service level when we have tight inventory spending budget and limited warehouse space. This model can decide service level for each group flexibly to maximize profit base on available inventory budget and warehouse space. Moreover, instead of allowing the program chooses the service level freely, we can control the range of service level that we want. It is suitable for inventory manager to plan the inventory policy in the diverse market situation.

CONCLUSIONS

In this study, we have developed an optimization model to improve a well-known ABC inventory classification approach by choosing an optimal service level for each group. There are two different things that make our model differs from the existing optimization model in the literature. First, our objective function is set to maximize profit which, to our knowledge, there was only one study conducted to maximize profit, while other studies focus on minimize total cost. Second, our solution provides the optimal service level within a limited inventory budget and warehouse space which is an important input for inventory managers. Our solution also helps inventory managers to choose the optimal service level when there are limited inventory budget and warehouse space, while the ABC approach cannot apply. The future study could focus on multiple criterions. We are also looking for possible to continue our research on perishable SKUs which has a shelf life and flexible overhead management cost which is a gap for future studies.

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