FUZZY INVENTORY MODEL ON VARIOUS LEAD TIME DEMAND USING MULTI CRITERIA CLASSIFICATION APPROACH: A LITERATURE REVIEW

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Abstract. *Inventory cost has become one of the major contributions to enterprise inefficiency. To minimize total cost, an enterprise is urged to manage an effective and efficient inventory system. In this case, an appropriate inventory model is in need. This study aims to propose an optimal inventory model by examining ABC multi-criteria classification approach using FANP (Fuzzy Analytical Network Process) and TOPSIS (Technique of Order Preferences by Similarity to the Ideal Solution) method. This study proposed a continuous review inventory model.*

Keywords: *Fuzzy inventory model, ABC multi-criteria classification, FANP and TOPSIS.*

1. Introduction

Inventory is one of the most expensive and important assets of many enterprises, representing as much as 50% of total invested capital (Balakrishnan *et al.*, 2011: 12-2). Inventory cost has become one of the major contributions to enterprise inefficiency. Therefore, to minimize the total cost, an enterprise is urged to manage an effective and efficient inventory system (Nahmias, 2004: 275). In this case, the design of an appropriate inventory model is in need

The main factors that should be noted to design the inventory model is that items held in inventory are not equal importance in terms of money invested, profit potential, sales volume, or stock out penalties (Godwin *et al.*, 2013). Differences in importance generally seen as opportunities to distinguish a limited number of inventory items in several classes, known as inventory classification (Kampen *et al.*, 2012).

Studies for inventory model that classified the differences in importance of the inventory items are still limited. Therefore this study purpose is to propose an appropriate inventory model using multi criteria classification approach.

2. Literature Review

2.1. Multi Criteria Inventory Classification

In order to create an inventory classification, two basic questions that need to answer are, how many classes are used and how the borders between the classes are determined (Kampen *et al.*, 2012). There is no fixed rule about the number of classes that used in the inventory classification. Previous studies have shown that using three classes in inventory classification is the optimal number and it is familiar for any enterprise. The number of inventory items does not affect determination of the number of classes. Rezaei *et al.* (2010), Torabi *et al.* (2012), Keskin *et al.* (2013) classify the raw materials amounting to an average of 50 items into three classes; Kabir *et al.* (2012) classifies 315 raw materials of construction industry into three classes; and Kartal *et al.* (2012) classifies 715 raw materials of automotive industry into three classes as well. Therefore, this study proposes to classify the inventory items into three classes: A (outstandingly important), B (of average importance), and C (relatively unimportant).

Determination of the borders between the classes affected by the classification criteria and classification techniques (Kampen *et al.*, 2012). The traditional ABC classification in generally just based on the annual dollar usage criteria. However, using single criterion is irrelevant in real life situations. Yu (2010) and Keskin *et al.* (2013) revealed that using the annual dollar usage criterion only might create problems of significant finance loss. Lead-time, criticality, durability, and so on are other important criteria that should be considered. Thus, to get the inventory classification criteria those are relevant, the enterprise should select their own criteria based on a master list of criteria that have been using in academic researches.

Multi criteria inventory classification is a part of Multi Criteria Decision Making (MCDM) problems. Kampen *et al.* (2012) distinguish this MCDM techniques into two types based on the knowledge source: the statistical and judgmental techniques. Statistical techniques knowledge sources are based on data of a number of inventory items characteristics. Yu (2010) and Fernandez *et al.* (2011) used the statistical techniques in classify inventory items. They used meta-heuristic approach. The advantage of statistical techniques is the classification result spared from subjectivity. However, these techniques have high level of complexity and the application of these techniques could become cumbersome for inventory managers especially there is no participation of the manager in it (Rezaei *et al.*, 2010; Kampen *et al.*, 2012).

In contrast with statistical techniques, the judge-mental techniques involve the opinions of manager especially in the determination of criteria weights. Some of judge-mental techniques had proposed by previous researchers. Such as *Technique of Order Preferences by Similarity to The Ideal Solution* (TOPSIS) by Bhattacharya *et al.* (2007), Fuzzy Analytic Hierarchy Process (FAHP) by Kabir *et al.* (2012), combination of Fuzzy Delphi and FAHP by Kabir *et al.* (2013), *Simple Additive Weighting* (SAW) by Kartal *et al.* (2013), and *Fuzzy Analytic Network Process* (FANP) by Kiris (2013).

The main advantage of TOPSIS and SAW technique is this techniques are practice and suitable for a relatively large amount of inventory. However, these two techniques do not have provisions to determine the weights of criteria. Compared to SAW, TOPSIS has advantages in determining the composite priority weight of alternatives that takes into account the closest distance to the positive ideal solution. The main advantage of AHP is this technique has consistency consideration in determine the weights of each criterion in which it can cover up the weakness of TOPSIS. However, the FAHP is still having an element of subjectivity and assume that each criterion is independent. Therefore, the extended version of FAHP technique, namely FANP can cover up the weakness of FAHP because this technique considers the dependency factor among criteria and it produces a more stable weight than FAHP.

Based on the advantages and disadvantages of the above techniques, this study proposes a combination of FANP and TOPSIS to classify the inventory items.

2.2. Inventory Model

There are two fundamental decisions that should be determined while designing an inventory model: when should an order be placed and how much should be ordered (Nahmias, 2004: 193; Balakrishnan *et al.*, 2011: 12-3 - 12-4). The complexity of the resulting inventory model depends upon the assumptions one makes about the various variables of the system. The variables are demand, lead-time, excess demand, inventory costs, and review time (Nahmias, 2004: 193-197).

These five variables determine the characteristic of inventory model. The functions of demand, lead time, excess demand characteristic are to determine the mathematical formulation of inventory model and become a numerical input to determine the order quantity (Nahmias, 2004: 196-197). The function of review time variable is to determine when an order should be placed based on the review time used (Nahmias, 2004: 244). Inventory cost variable is the main variable that is optimized in the inventory model formulation (Nahmias, 2004: 197).

The determination of the characteristics of these variables needs to adjust to the subject of the study because the proposed model designed not only to describe the situation of a system but also provides the best answer to the inventory problem.

Demand variable is distinguished into two types: known demand (deterministic model) and uncertain (stochastic model) (Nahmias, 2004:196). This study uses uncertain demand model. It means that the exact number of future demands cannot be predicted at the beginning. The uncertain demand variable is influenced by lead-time variable (Nahmias, 2004:197). In this case, although the future demand cannot be predicted at the beginning, one's past experience can be provide useful information for planning. The random demand in the past can be used to estimate its lead-time demand probability distribution. Previous studies generally assumed the lead time demand distribution is uniform for all inventory items, such as entirely normal distribution (Silver *et al.*, 2011, Joshi *et al.*, 2011, Zheng *et al.*, 2011; Sadi-Nezhad *et al.*, 2011) or uniform and exponential distribution (Taleizaideh *et al.*, 2013) without statistical testing, whereas the different type of distribution affects the value of decision variables. For this reason, the study proposes to examine the lead-time demand distribution type before formulate the inventory model.

Another important characteristic that determines the inventory model formulation is how the system reacts to excess demand (Nahmias, 2004: 197). In a study of inventory model, there are two choices assumptions used by the researchers. The most dominant assumptions used for compliance with the real life situations is, to do a backorder (Jaggi et al., 2012; Zheng et al., 2011; Sadi-Nezhad et al., 2011). Other assumptions are losing the customers (lost sales) (Nagasawa, Irohara, Matoba, and Liu, 2013). This study propose to do backorder system in which the system will satisfy the customer's need at the future time.

Determination of inventory model especially on what variables to be decided influenced by review time variable. Review time variable distinguished into two types, continuous review and periodic review (Sipper *et al.*, 1997: 211; Nahmias, 2004: 244). Determine the review time variable should be adjusted to the importance of inventory item on company performance (Nahmias, 2004: 276; Motadel *et al.*, 2012). Previous studies that consider the importance of inventory item in review type determination are still limited. Aisyati *et al.* (2013) for example, who designed the continuous review inventory model for class A and B items. Continuous review inventory model considered suitable for class A and B items that have high costs because this model gives the amount of safety stock that is smaller than the periodic review models. In addition, based on the characteristic of continuous review model where fixed quantity ordering, the supplier becomes easy to predict the order quantity. The use of continuous review inventory model to the class A items is also supported by Nahmias (2004: 276). For these reasons, this studi proposes to use this continuous review inventory model.

Variable that become optimization criterion in designing an inventory model is inventory cost. In fact, estimating the exact value of cost variable may not be possible (Sadi-Nezhad *et al.*, 2011; Prasath *et al.*, 2012; Jaggi *et al.*, 2012; Dutta *et al.*, 2012). Inspired by the concept of fuzzy sense, this study proposes to adopt this concept in the cost variable. In the fuzzy sense, two main things need to be determined. They are the fuzzy membership function and defuzzification technique.

Previous studies who designed the fuzzy inventory model usually use triangular membership function. For example, Joshi *et al.* (2011), Zheng *et al.* (2011), Sadi-Nezhad *et al.* (2011), Prasath *et al.* (2011), and Jaggi *et al.* (2012) that did not explain why they choose triangular membership function in their studies. Dutta *et al.* (2012) examined this uncertainty in the design of EOQ model then. In his study, Dutta *et al.* (2012) found that the trapezoidal membership function gives better results and economic compared with triangular membership function. As well as fuzzy membership function, several previous studies also used defuzzification techniques without a clear explanation of the basis for selection of such techniques. Joshi *et al.* (2011), Zheng *et al.* (2011), and Dutta *et al.* (2012) used signed distance method in their studies. Prasath *et al.* (2012) using the centroid method in their study. Finally, Jaggi *et al.* (2012) tried to compare the three of defuzzification techniques: graded mean integral representation, signed distance and centroid method in the design of EOQ models. Based on the findings of Dutta *et al.* (2012) and Jaggi *et al.* (2012) studies, this study will use trapezoidal membership functions and graded mean integral representation defuzzification technique in stochastic inventory model environment.

3. Proposed Inventory Model

Based on the critical reviews of the previous studies that have been described above, this study intends to fill the gap between previous studies and real life situation. The previous studies did not consider the importance level of inventory items in determining the type of review time is used so that all items have same inventory model, equated the type of lead time demand distribution without prior testing, assumed inventory model variables regardless of the object under study, used defuzzification technique and the membership function that are used the majority of previous studies without a clear basis, and just gave the value of output variables for each item without ensuring that the model can be used if the value of input variables are changed.

Based on these gaps, this study proposes to design a continuous review stochastic inventory model with a ABC multi-criteria classification approach. Combination of multi-criteria classification technique, Fuzzy Analytic Network Process (FANP) and TOPSIS are suggested based on previous literature review. The use of FANP and TOPSIS technique is the novelty of this study in the related literature about inventory classification. Continuous review inventory control model proposed in this study is a stochastic model with statistical testing of lead-time demand distribution, and using fuzzy sense in the cost variables. Applying the graded mean integral representation defuzzification technique and trapezoidal membership function in the stochastic inventory model is also the novelty of this study in the related literature.

The fuzzy continuous review inventory model using multi-criteria ABC classification approach that proposed for designing appropriate inventory model in this study supported by Aisyati *et al.* (2013) study. Aisyati *et al.* (2013) who used a continuous review inventory model for class A and B found that there are several items show that existing model performs better than continuous review model. It can be said that the percentage of saving is negative. In their analysis, Aisyati *et al.* (2013) explained that the continuous review model could fail to result better inventory model since the demand of the items is too lumpy or lead-time demand has a Poisson distribution pattern. Aisyati *et al.* (2013) also recommended that this Poisson demand could be managed by periodic review inventory model. Aisyati *et al.* (2013) used traditional ABC classification in their study. It means that the class A items are high value inventory based on the dollar usage only. Consequently, although the demand of a high cost item is too lumpy, it will be classified as class A. Thus, the design of the inventory model using ABC multi criteria classification approach would be more effective in saving the inventory cost than using traditional ABC classification.

4. Future Research Design

Figure 1 below is the steps to develope the future research design for proposed inventory model based on literature review.

First, determine the classification criteria and their weights. The five fuzzy scales defined by Kahraman *et al.* (2006) is suggested to use in Fuzzy Analytic Network Process (FANP) approach to determine the weights of the classification criteria. The second step, determine the composite priority weights of inventory items. TOPSIS technique is propose to determine the composite priority weight of each item. The third step, traditional ABC multi criteria classification approach then used to classify the inventory items into three classes. Borders between classes should be determined by enterprise. The fourth step, design the appropriate mathematical formulation of fuzzy continuous review inventory model for class items based on lead-time demand distribution after the pattern of lead-time demand distribution was tested.

The final step, evaluate whether the proposed model can solve the inventory problems of the enterprise. Comparison of Inventory Turnover Ratio (ITR) and inventory total cost between the proposed and existing model is sugested. ITR comparison use to evaluate the overstocking level of the proposed model. Comparison of inventory total cost use to evaluate the proposed model from financial aspect.

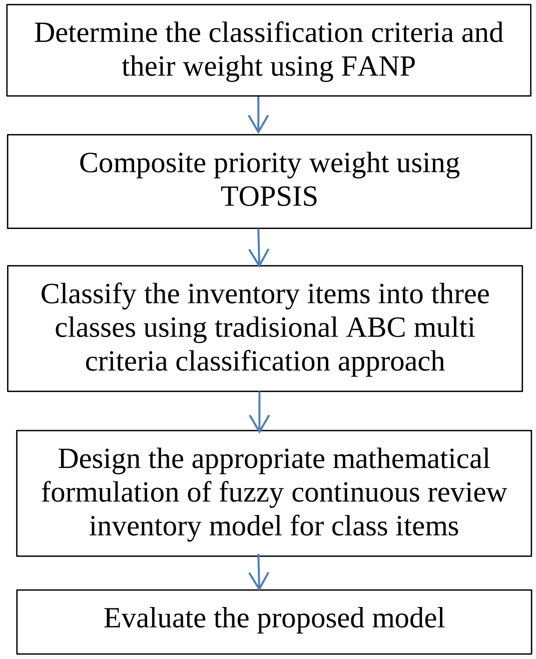

Figure 1 : The steps to develope the future research design for proposed inventory model.

5. Conclusions

To design a continuous review stochastic inventory model, Fuzzy Analytic Network Process (FANP), TOPSIS and ABC multi criteria classification approach proposed to classify the inventory items, especially a relatively large amount of inventory. Since the lead-time demand distribution is not always normally distributed, it needs to be tested before design the mathematical formulation of inventory model. This study proposes a fuzzy continuous review inventory models using graded mean integral representation defuzzification technique and trapezoidal membership function to be applied in stochastic inventory model environment.

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