COMPREHENSIVE ANALYSIS OF CURRENT FUZZY EOQ MODELS

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Abstract. Inventory management and fuzzy set theories have been investigated and published only in Elsevier throughout the years to incorporate these concepts into this research stream. A systematic and comprehensive analysis of current advances in the fuzzy inventory management field is needed, which prompted us to highlight key developments and cast light on future research. First, recent publications are evaluated and presented to illustrate the significance of this topic. The methodology used to obtain sample papers is discussed, and the papers are then analysed in order inventory. Several model components were evaluated, resulting in the discovery of several areas previously neglected by researchers.

INTRODUCTION

Inventory management is undoubtedly one among the toughest challenges for firms in today's competitive industry. The principal goal of this research is to provide contribute toward filling up the research gap in Fuzzy Inventory Models. Inventory constitutes the most important part of the industry. The aim of inventory management is to prevent retaining excessive stock. It is critical to manage stocks efficiently to save costs of change in production rates, unessential cost of sales, and backorder penalties during periods of peak and fluctuating demand. For any given stock, only two questions: when and how much are ever really settled. The production-inventory control model includes the Economic Production Quantity (EPQ) model of how much to produce and the Economic Order Quantity (EOQ) model of how much to order, which are used to establish the optimum production and purchase order amounts, respectively. EOQ model, created by F.W. Harris, was expanded upon in 1918 by E.W. Taft, giving rise to the EPQ model.

Inventory model makes similar assumptions about the basis of the demand, the product's quality, the inspection process and errors made during inspection, the deteriorating goods, etc. On other hand, there are several purposes for the EOQ model. These models handle various industrial planning requirements and constraints. Zadeh pioneered the concept of Fuzzy set theory during 1965. He devised one of the effective methods for overcoming these constraints. During 1970, Zadeh, Bellman introduced decision making problem to Fuzzy set.

Tanaka et al. defined fuzzy objectives with a fuzzy constraint in 1974. Zimmermann (1976) proposed that multi-objective linear programming issues be solved using fuzzy programming. Inventory systems are now using fuzzy set theory. For production and inventory problems Fuzzy concept was used by Sommer in the year 1981. Fuzzy set theoritical technique to study the EOQ formula was used by Park during 1987, linking fuzziness with costing. Single objective Fuzzy EOQ model using the Geometric Progression (GP) technique was solved by Roy et al. during 1997. The GP methodology, first published in the year 1967 by Duffin et al, it is a powerful methodology for addressing non-linear programming problems. The GP technique was initially used to foundational inventory problem by Kotchenberger (1971). De et al. (2001) developed a replenishment policy based on the extension principle for objects with a limited production rate and a fuzzy degradation rate depicted by a triangular fuzzy number. Jain (1976) was the first to suggest the methodology of sorting fuzzy numbers.
Apart from fuzzy EOQ while considering general EOQ models different models and optimization techniques have been introduced a variety of other models and optimization strategies have been developed in addition to fuzzy EOQ while taking generic EOQ models into consideration. Zhanbing Guo et al. [1] constructed an adaptive EOQ (AEOQ) policy, and they investigated the efficacy of the AEOQ policy from the viewpoints of both stability and profitability. In addition, the delayed feedback control approach may be used to stabilize this iterative operation if fluctuations take place. In the first step of profitability analysis, three objective functions are presented, and it is shown how the relative difference in order quantities between equilibrium and ideal may be modified by important characteristics. By defining the AEOQ policy as an effective solution, if the equilibrium order quantity was able to strike a balance with the purpose. Mojtaba Mahdavi et al. [2] works on the conceptual framework developed by Fisher (1997) for the construction of effective supply chains for functional items a difficulty with the supplier selection for the sort of product that is being evaluated, as well as the creation of a continuous review inventory model that includes EOQ ordering that reflects Fisher's (1997) qualitative discussion. According to the findings of our research, an excessively optimistic outlook about the projection regarding the service level for a novel product is indicative of picking the appropriate supply chain. Valery Lukinskiy et al.[3] developed a perfect-order computation is often used in order to evaluate a supplier's dependability as well as their performance in terms of order fulfilment. examines many distinct approaches to the probabilistic evaluation of a perfect order and suggests a method for determining how the valuation of a perfect order is affected by variations in the probability of its parameters and the number of those parameters. An analytical technique that makes use of discrete distributions of random variables serves as the foundation for the suggested models. Michalis Deligiannis et al.[4] has suggested that the service-driven always-a-share conduct of a company may have a substantial impact on the cooperative and competitive inventory policies of the company's suppliers. Designers look at a model of a recurring customer that splits their business between two different types of newsvendors over an unlimited time horizon. pure- strategy A solution based on the Nash equilibrium has been implemented. Morteza Yazdani et al.[5] has implemented this concept, because of the important part it plays, a food supply chain, also known as an FSC, is an important part of the global supply chain. Any disturbances or dangers in FSC management (FSCM) might lead to

repercussions that are both irrecoverable and expensive. A decision-making model was addressed, and in it, the best worst method (BWM) and fuzzy measurement of alternatives and ranking as according to compromise solution (fuzzy MARCOS) were used to test the resilience of key participants in the FSCM in relation to a variety of risk variables and other types of resiliency. M.Ghanbarzadeh-Shams et al. [6] has developed a model in the carpet industry, reverse logistics operations are challenging and highly vulnerable to uncertain affecting the collection rate, recoverable items' ease of access, and reverse channel capacity A novel fuzzy multiple-objective programming model has been proposed with chance constraints. Novel hybrid fuzzy goal programming is proposed for solving the developed model. Erfan Babaee Tirkolaee et al. [7] presents a fuzzy bi-level Decision Support System (DSS), with the goal of optimising a sustainable multi-level multi-product Supply Chain (SC), as well as a co-modal transportation network, for the distribution of perishable items. In order to account for the bi-level model that we have proposed, a hybrid method to problem solving that is based on possibilistic linear programming and the Fuzzy Weighted Goal Programming (FWGP) approach has been devised. The unpredictability of the situation may be managed with the help of this strategy, which also protects the integrity of the whole system. Mohammad Shafiee et al. [8] concentrated his research on the decision-making trial and evaluation laboratory technique, which was utilised to analyse the hazards to perishable product supply chain networks during the time of the coronavirus epidemic. Pythagorean fuzzy sets are used in order to take the uncertainty of the experts' judgments into account when conducting analyses. These analyses demonstrated that the perishability of goods, harmful working conditions, supply-side risks, and work-hours are extremely influential risks that have the potential to easily affect other risk factors. As a result of this study's practical findings, managers and other decision-makers have access to a broad variety of insights that may help them reduce risks to supply chain networks for perishable products during the period when the coronavirus epidemic was occurring. The paper's key themes are constructing a mathematical fuzzy model and implementing a fuzzy solution. Over all, only the papers applying fuzzy solutions are extracted for our analysis. This review work focuses only on fuzzy-based inventory management. Today's business world is dynamic and competitive, the inventory management system is not as precise as standard models presume.

LITERATURE SEARCH

The keywords were segregated into two categories: the first group contained terms related to inventory management, which were "inventory management," "inventory model," "EOQ model," "lot-size," "lot sizing inventory," and "inventory." Fuzzy Set Theory was the following set of phrases, in which "fuzzy EOQ model," "fuzzy set," "fuzzy," "fuzzy number," and "membership function" were defined. Articles were separated into several categories based on the research keywords after a comprehensive assessment of the literature, and the primary material of every paper was compared, analyzed and studied.

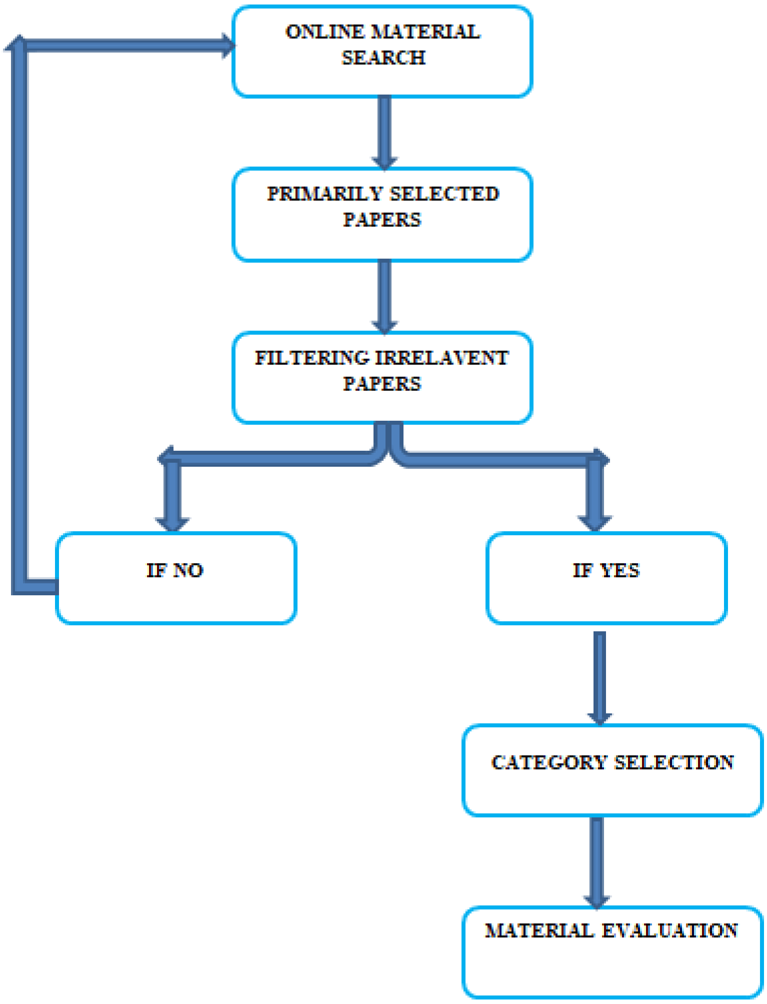

FIGURE 1 PAPER SEARCH TECHNIC

FUZZY EOQ LITERATURE

It is unavoidable in the manufacturing industries for storage cost, ordering cost, and backordering costs to vary from one iteration to the following. The quantity of order or demand may fluctuate from time to time based on the conditions. K.S. Park et al.[9] was the first to initial the present Fuzzy EOQ Model. Later, M. Hojati et al [10] enhanced and expanded it by pointing out several drawbacks. H.-M. Lee et al. and L. Lin et al. [11] examined the fuzzy model of inventory using the signed distance approach. S.-H. Chen at el. [12] was pioneered the development of a Fuzzy EOQ model with the back ordering. Order and the shortage quantities are fuzzified in J.-S.Yao et al. [13] and S.-C. Chang et al. [14]. Fuzzy model for two storages specially, for degrading goods in probabilistic schedule for horizon with an exponential distribution function was developed by A. Roy et al. [15]. A model for two ware-house for degrading commodities with the lead time in terms of fuzzy with set up cost which are time dependent was proposed by M. Rong et al. [16]. W. Hsu et al.[17] investigates a fuzzy inventory model with quick returns for faulty products. A unique solution approach was created by K. Das et al. [18] for a multi-item fuzzy-stochastic inventory model. Two fuzzy multi-item, multi-objective inventories with stock-dependent demand was created by T. Royet al. and M. Maiti et al. [19].

FUZZIFIED ELEMENTS

The total number of components that have been fuzzy-tuned is substantial. Instead of fuzzifying variables in general, the authors fuzzy-checked the parameters. In addition, the majority of the related pieces that were fuzzified up were fuzzified. Another component that has received a great deal of attention is the frequency of certain aspects, such as the demand rate and parameters considered for the inventory cost, which were found to be the sections of the papers that were most often clouded by uncertainty. Additionally, models that are completely fuzzified in every aspect are one of a kind in every respect. We could find other kinds of variables among the fuzzy components, such as fuzzy stochastic variables, intuitionistic fuzzy variables, bi-fuzzy variables, and so on.

MEMBERSHIP FUNCTIONS

Any fuzzy inventory model absolutely must include a membership function as one of its core components. A comparison of the membership functions in terms of the number of times each function was mentioned in the articles that were examined. A significant number of articles make use of more than one membership function.

CONTENT REVIEW

To emphasize the importance of the current work, we examined numerous current emerging papers in the field of inventory management. The following tables 1 and 2 represents the classification of papers based on their parameters and fuzzy numbers respectively, also followed by the review of the recent chosen papers based on their fuzzy techniques used.

TABLE 1: LIST OF PARAMETERS CLASSIFIED BASED ON THE PAPERS

Papers	BACKLOGGING	PRE-PAYMENTS	DELAY PAYMENTS	PARTIAL TRADE CREDIT	SHORTAGE	DETERIORATION	FUZZY REASONING	BACKORDER	IMPERFECT	INSPECTION ERROR
[20]		✓					✓			
[21]				✓			✓			
[22]	✓						✓			
[23]	✓						✓			
[24]					✓		✓			
[25]		✓				✓	✓			
[26]							✓			
[27]					✓		✓			
[28]							✓			
[29]						✓				
[30]							✓	✓		

[31]			✓				✓			
[32]							✓	✓		
[33]							✓			
[34]	✓						✓			
[35]					✓		✓		✓	✓

TABLE 2: CLASSIFICATION OF FUZZY NUMBERS USED IN THIS PAPERS

Papers	TRIANGULAR FUZZY	HEXAGONAL FUZZY	TRAPEZOIDAL FUZZY	PENTAGONAL FUZZY	INTERVAL NUMBER
[20]	✓	✓	✓	✓	
[21]	✓				
[22]	✓				
[26]		✓			
[29]	✓				
[30]	✓				
[31]			✓		
[32]	✓				
[34]					✓
[35]	✓				

STATERGIES AND FUZZY TECHNIQUES USED

On studying and analysing the papers considered for the review paper, we could discover many different types of fuzzy demand, fuzzy numbers, algorithms, tools and techniques. On examining the research papers Hemalatha .S et al. [20] represents the cost components are represented as triangular, trapezoidal, pentagonal, and hexagonal shapes. The overall inventory cost is defuzzed using the graded mean integration approach, and the ideal replenishment cycle is found using the extension of the Lagrangian method, but the ultimate aim is to reduce the suggested inventory model's overall cost. Out of all the fuzzy numbers, trapezoidal fuzzy number gives the optimum solution, and we get the minimum total cost. when we defuzzify the trapezoidal fuzzy number using graded mean integration method. Triangular fuzzy number gives maximum total cost when compared to other fuzzy numbers. The (EOQ) model Gour Chandra Mahataa et al. [21] approaches for a merchant with two tiers of trade credit is examined in this research in order to describe the management of supply chains scenario in a fuzzy perspective. It is expected that the triangular fuzzy values used for the demand rates, holding costs, ordering costs, buying costs, and selling price are correct. The Graded Mean Integration Representation approach is used to defuzzify the retailer's yearly total variable cost in a fuzzy sense. In order to effectively identify the inventory strategy that will be most beneficial for the merchant, mathematical theorems and algorithms are devised. The idea of learning through fuzziness is one of the techniques which was put out by Glock et al., in 2012. Nima Kazemi et al. [22] deals with Backorders in an EOQ model with fuzzy lead times and demand. Whereas learning in fuzziness lowers the overall cost of inventory. Comparisons are made between the best policies for three models: learning in fuzziness, crisp, and fuzzy and also to determine the ideal total yearly cost and ideal number of orders, an algorithm is suggested. The Holland genetic algorithm (GA) is a population-based stochastic search and optimization method that functions similarly to natural selection. Binary strings of 0s and 1s are used in (GA) to represent candidate solutions. The cost of the yearly inventory was intended to rise along with credibility's increased worth. Additionally, as the model's complexity increases, the PSO method may function best than that of the (GA) in respect of both its greater credibility and its lower resource need. It could have occurred as a result of the particles' built-in intelligence in the PSO algorithm. N.K. Samal et al. [23] determines the ideal EOQ, which would minimise the fuzzy anticipated value of the total cost and maximise the confidence that the total cost would not exceed a certain budget level, fuzzy expected value models and fuzzy dependent chance programming models were developed. Particle swarm optimization and genetic algorithms were both used for optimization, and their results were compared. Promotional index (PI) is one among the technique which was used for the fuzzy variable to be determined by, Sujit Kumar De [24], the membership function of the fuzzy (PI) follows a triangular fuzzy number in order to solve the issue using Yager's (1981) ranking index approach. Yager's ranking index method, R.R. Yager presented an approach to the ordering of fuzzy sets that was predicated on the idea of area compensation. Linearity is a property that is possessed by the process of area compensation. We have utilised an improved variant of the crisp optimum solution expressed in terms of the PI variable so that we may design a fuzzy issue, because the function for calculating profit is convex. The characteristics of the average profit function for the traditional backorder model when the promotional effort is taken into account and all of the decision factors are treated as fuzzy variables. The swarm intelligence-based Meta-Heuristic Algorithm is used in many of the research papers. Where Ata Allah Taleizadeh et al. [25] puts up against other Meta heuristic algorithms like the Genetic Algorithm, Particle Swarm Optimization, Harmony Search, Simulated Annealing, Tabu Search, Neural Network, and Variable Neighbourhood Search, the Bees Colony Optimization (BCO) algorithm comes out on top when it comes to quantity discount and prepayment. The Geometric Programming (GP) methodology is well utilized with special specifications for only certain categories of optimization problems. In general the Inventory model which are solved with (GP) problem, and the membership functions of the fuzzy profitability and choice variables are mathematically derived by making use of the most recent developments in fuzzy optimization algorithms and the extended with (GP) approach. In order to cut down on the overall cost, K. Kalaiarasi et al. [26], has classification techniques, signed-distance method, and graded-mean representation method are three distinct defuzzification methodologies that are utilised. The (GP) method is utilised to rectify the crisp inventory model, the fuzzy inventory model is solved using hexagonal fuzzy numbers. Both of these models are solved by utilising the hexagonal fuzzy numbers. The crisp and fuzzified figures are calculated using Python code, which significantly reduces the amount of time required in contrast to calculations performed by humans. Where Dorigo developed Ant Colony Optimization (ACO) in the 1990s, this technique was used by Ali Roozbeh Nia et al. [27] a multiple-item EOQ model was constructed with shortfall under a vendor-controlled inventory policy takes place in a supply chain that consists of a single vendor and a single customer. This technique that was offered was the one that was best in terms of the overall cost. It is one of the most advanced approaches to approximation optimization, and it has been put to use to solve a wide range of issues that are encountered in the real world. Where Sujit Kumar De et al.[28] conventional fuzzy duality issues, there has been no discovery of a duality gap; nevertheless, in this fuzzy reasoning dual-space problem, there is always a duality gap. On comparing many papers, triangular fuzzy numbers where utilized to maximise the overall profit. R. Srinivasan et al. and V. Vijayan et al. [29] deals with unit of time for degrading goods when the parameters are fuzzy triangular numbers, the calculations are also done on the approximate total cost each cycle in the storage house and the showroom. The optimal results obtained from the model were defuzzified and used as the centroid for the ranking approach known as centroid ranking. Because of this, the overall profit will be higher and also M. Nagamani et al. and K. Kalaiarasi et al. [30] deals with triangular fuzzy number which is subjected to fuzzification and defuzzification with the help of yager's approach to establish the optimal order quantity with stochastic lead time and reduced and fuzzy demands.

Anu Sayal et al. [31] has taken an inventory of non-perishable items into consideration for this research where the rate of demand is dependent on the passage of time, and a certain amount of delay in payments is allowed, comparison of the crisp and fuzzy surroundings is carried out for your viewing pleasure. These values are then defuzzified by the use of the centroid approach, the trapezoidal fuzzy number is used for this. It is possible to compute, for both fuzzy and crisp systems, the optimal value for the overall cost and the order quantity by taking into account a variety of scenarios. Where M. Rong et al. and M. Maiti et al.[32] has developed a controlled lead-time and fuzzy stochastic demand, the EOQ model has level of service constraints. The unfulfilled demands are partly backordered, and both the lead-time and the order quantity are regarded to be the decision variables. The weekly demand as well as the anticipated daily total cost is a fuzzy figure in the shape of a triangle. Then, in order to defuzzify the data, we employ a technique called signed distance. This paper presents a sophisticated approach for determining the best order quantity and reordering point in such a way that the total estimated yearly cost has a value that is as close to zero as possible. In this particular piece of research Sujit Kumar De et al.[33] has presented a novel idea of fuzzy set known as the hesitant fuzzy set (HFS). The decision is made solely on the basis of the HFS scores, this procedure could be trialled to use other operators relating to an intuitionistic fuzzy set (IFS) theory. The primary objective of this model is to choose the optimum solution in the face of uncertainty and other considerations. Sujit Kumar De et al. [34] has presented a fuzzy version of the EOQ crisp model with back log inventory. The demand from consumers changes depending on the selling price and the amount of effort put into promotional activities. The cost function includes the costs associated with setting up, maintaining inventory, making up for shortages, and making promotional efforts. The function for minimising the total cost. Where engineering challenge involves in fuzzy EOQ model, Jicheng Liu et al. [35] has characterised by unsatisfactory quality and shortages. The proportion of faulty products, which is shown as a fuzzy number with three angles. In order to realise the greatest amount of profit, it is essential that inspection mistakes and the percentage of products that are flawed be reduced to an absolute minimum. Preety Poswal et al.[36],estimates of optimal quantity fuzzy EOQ model for perishable goods with price-sensitive and stock-dependent demand functions in the presence of acceptable shortages. It is assumed that the demand function is sensitive to price and stock dependant. Following the development of a clear model, the purchasing cost, storage cost, degradation rate, and shortfall cost were each represented by a fuzzy trapezoidal number. Using a signed distance approach, the total cost functions may reduce their fuzziness using a signed distance approach, the overall cost functions may have their fuzziness reduced. Modeling an EOQ system for non-perishable goods is the focus of AnuSayal et al. [37], the optimum policy is designed to ensure that consumers pay as little as possible regardless of any payment delays that may occur. Demand growth is time-sensitive. Both crisp and fuzzy systems are used in the model's development.

APPLICATIONS & SCOPE

The majority of inventory-related needs in today's economic, technological, and environmental decision-making issues are not deterministic, but rather uncertain. The features and limitations of these models couldn’t be completely recognised unless it’s implemented using real life data or applied to real-world scenarios. These models often fuzzified certain parameters or variables. As a result, future research might perform case studies to get insights from practical aspects. As we knew, the real-life business environment which always fluctuates. On developing well furnished, fuzzified inventory model can better illustrate the interactivity of the current real-world scenario than by addressing the intricate structure of these models. It might be a challenging and fascinating concept to consider how we could strengthen the model's tolerance to tolerate the pliability of real-world data. Because environmental influences can raise the Fuzzy set theory which may be a beneficial tool in inventory system due to unpredictability of an inventory system for controlling uncertainty.

FUTURE RESEARCH IMPLIMENTIONS

Our thorough examination revealed that several classifications of Inventory models under the area of fuzzy systems were proposed in the prior studies. The models established presume the parameters which are unknown, it can be determined and depending on the experience of the authors. Although researchers placed a strong emphasis on the human element in their model, they also incorporated cognitive beings and qualities such as training, making errors, and deterioration of knowledge. The parameters used in the model and its overall effectiveness are both significantly impacted by human characteristics.

One of our study's limitations was that we confined our search to articles that were currently available. In contrast to real-world environments, fuzzy inventory models may provide overstated or underestimated findings. Fuzzy set theory is an effective and an efficient tool for inventory system to regulate uncertainty. Combining these two intriguing fields might lead to a new research approach. LINGO, LINDO and some of the optimization toolbox applications like MAPLE, MATHEMATICA, MATLAB are utilised. Furthermore, C, FORTRAN are some of the programming language which are capable of solving the models.

CONCLUSION

This paper's objective was to provide a thorough analysis of research on fuzzy inventory models, which have emerged over past 12 years. We rigorously read and analysed the publications in each research stream to identify important breakthroughs and research needs. On reviewing these papers on inventory model and control management, it was helpful at the point where the authors were able to compare various sample papers, categorizations, and benchmarks with analytics.

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