Chapter 2

A Neutrosophic Approach to Inventory Modelling under Uncertain Demand

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Abstract

Inventory management plays an important role in ensuring the efficient flow of goods while maintaining a balance between supply and demand. Most classical inventory models assume that parameters such as demand, ordering cost, and holding cost are known precisely. In real-world situations, however, these parameters are often subject to uncertainty and incomplete information due to fluctuating market conditions and estimation errors. As a result, deterministic models may not always capture the complexity of practical inventory systems.

To address this limitation, the present chapter explores an inventory modelling approach based on neutrosophic theory. Neutrosophic representation allows uncertainty to be expressed through three independent components: truth, indeterminacy, and falsity. This framework provides greater flexibility for modelling situations where

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information is not completely certain or may contain indeterminate elements.

In the proposed model, demand is represented in a neutrosophic form while the cost structure follows the conventional inventory framework consisting of ordering and holding costs. A neutrosophic total cost function is formulated and analysed to determine the inventory policy that minimizes the overall cost of the system. The mathematical formulation is supported with a numerical example to demonstrate the practical applicability of the model.

A comparison with the classical deterministic inventory model is also presented to highlight the effect of incorporating neutrosophic parameters. The analysis shows that the neutrosophic approach provides a broader representation of uncertainty while retaining the interpretability of traditional inventory models. The study illustrates how neutrosophic theory can be effectively applied to inventory decision-making problems involving indeterminate information.
Keywords: Neutrosophic set; Inventory management; Inventory model; Uncertainty modeling; Total inventory cost; Optimization.

1. Introduction

Inventory management is a fundamental aspect of supply chain and production systems. Organizations rely on efficient inventory policies to ensure that products are available when needed while avoiding excessive storage costs. Maintaining this balance between supply and demand is often challenging, particularly when demand patterns are uncertain or difficult to predict. For many years, classical inventory models have been used to determine optimal ordering policies by minimizing the total cost associated with inventory operations. These costs typically include ordering costs incurred when replenishing stock and holding costs related to storing items over time.

Traditional inventory models generally assume that key parameters such as demand rate, ordering cost, and holding cost are known with certainty. Although this assumption simplifies the mathematical formulation of the model, it may not accurately represent real-world situations. In practice, demand may vary due to changing customer preferences, seasonal trends, or unexpected market conditions. Similarly, cost parameters may not always remain fixed, and in some situations the available information about these parameters may be incomplete or indeterminate. Because of these factors, decision makers often face difficulties when attempting to apply deterministic inventory models to practical problems.

To overcome these limitations, researchers have introduced different mathematical frameworks that allow uncertainty to be incorporated into inventory models. One such approach is neutrosophic theory, which provides a flexible way to represent uncertain and indeterminate information. In contrast to classical and fuzzy approaches, neutrosophic sets describe information using three independent components: truth, indeterminacy, and falsity. This structure makes it possible to represent situations where the available data is partially known or contains elements of ambiguity.

Motivated by these considerations, this chapter presents an inventory modeling approach that incorporates neutrosophic representation into the traditional inventory framework. In the proposed model, demand is expressed in neutrosophic form while the cost structure retains the conventional components of ordering and holding costs. The resulting neutrosophic total cost function is analysed to

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determine the inventory policy that minimizes the overall system cost. A numerical illustration is provided to demonstrate the applicability of the model, and the results are discussed to show how the neutrosophic approach can assist decision makers in handling inventory problems involving uncertain or indeterminate information.

2. Neutrosophic Concepts

Uncertainty is a common characteristic in many real-world decision-making problems. In inventory management, parameters such as demand, lead time, and cost components may not always be known precisely. Classical inventory models typically assume deterministic values for these parameters, which simplifies the mathematical analysis but may not accurately represent practical situations. To overcome this limitation, different mathematical frameworks have been introduced to incorporate uncertainty into modelling approaches. One such framework is neutrosophic theory.

Neutrosophic theory was introduced by Florentin Smarandache and provides a generalized approach for handling uncertain, indeterminate, and inconsistent information. Unlike classical set theory and fuzzy set theory, neutrosophic sets describe information using three independent membership functions: truth membership, indeterminacy membership, and falsity membership. This structure allows uncertain information to be represented in a more flexible manner. Let Xbe a universe of discourse. A neutrosophic set Adefined on $X$is expressed as

$$A = \{\langle x,\ T_A(x),\ I_A(x),\ F_A(x)\rangle \ \mid \ x \in X\}$$

where

$T_A(x)$denotes the **truth membership function**, $I_A(x)$denotes the **indeterminacy membership function**, and

$F_A(x)$denotes the **falsity membership function** of the element $x$with respect to the set A.

These functions represent the degree to which an element belongs to the set, the level of indeterminacy associated with the information, and the degree to which the element does not belong to the set.

The membership functions generally satisfy

$$0 \leq T_A(x),\ I_A(x),\ F_A(x) \leq 1$$

for all $x \in X$.

In practical applications, uncertain quantities are often represented using neutrosophic numbers. A neutrosophic number can be written as

$$\tilde{A} = (T, I, F)$$

where T, I, and Fdenote the truth, indeterminacy, and falsity components respectively. This representation enables uncertain parameters to be modeled more effectively than traditional deterministic values.

In the present study, neutrosophic representation is used to describe uncertainty in demand within the inventory system. By incorporating neutrosophic concepts into the inventory framework, the proposed model is able to capture the presence of indeterminate information and provide a more realistic representation of practical inventory decision-making situation

3. Model Assumptions

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To develop the proposed neutrosophic inventory model, the following assumptions are made in order to define the structure of the inventory system and simplify the mathematical formulation.

1. The inventory system considers a single product and a single warehouse.
2. The planning horizon is assumed to be infinite and the inventory process repeats over identical cycles.
3. The demand rate is uncertain and is represented using a neutrosophic number in order to capture the presence of indeterminacy in demand estimation.
4. The replenishment of inventory is instantaneous, meaning that the ordered quantity arrives immediately when an order is placed.
5. The lead time is assumed to be zero and remains constant throughout the inventory cycle.
6. Shortages are not permitted in the inventory system. The inventory level is replenished before it reaches zero.
7. The ordering cost per order is constant and is denoted by (K).
8. The holding cost per unit per unit time is constant and is denoted by (h).
9. The demand rate remains constant within each inventory cycle, although its value is expressed in neutrosophic form.
10. The deterioration of items is not considered in the present model.

11. The decision variable of the model is the order quantity (Q), which represents the number of units ordered during each replenishment cycle.
12. The objective of the inventory system is to determine the optimal order quantity that minimizes the total inventory cost.

These assumptions provide a simplified structure for incorporating neutrosophic representation into the classical inventory framework. Based on these assumptions, the mathematical model for the neutrosophic inventory system is developed in the next section.

4. Mathematical Model

Based on the above assumptions, the inventory model is developed by incorporating neutrosophic demand into the classical inventory framework. The objective of the model is to determine the optimal order quantity that minimizes the total inventory cost.

Let the demand be represented as a neutrosophic number

$$\widetilde{D} = (T, I, F)$$

where T, I, and F denote the truth, indeterminacy, and falsity membership values respectively.

Since the demand is expressed in neutrosophic form, a representative demand value is obtained for computational purposes as

$$D = \frac{T + I + F}{3}$$

Let the following notations be used:

Q– Order quantity per cycle

K– Ordering cost per order

h– Holding cost per unit per unit time

D– Representative demand value obtained from the neutrosophic

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demand

The ordering cost of the system is given by

$$OC = \frac{DK}{Q}$$

The holding cost is expressed as

$$HC = \frac{Qh}{2}$$

Thus, the total inventory cost is

$$TC(Q) = \frac{DK}{Q} + \frac{Qh}{2}$$

To determine the optimal order quantity, the total cost function is minimized with respect to Q. The optimal order quantity is obtained as

$$Q^* = \sqrt{\frac{2DK}{h}}$$

The value Q^*represents the optimal order quantity that minimizes the total inventory cost under neutrosophic demand conditions.

5. Numerical Example

To illustrate the applicability of the proposed inventory model, a numerical example is considered.

In the neutrosophic framework, demand can be represented using truth, indeterminacy, and falsity components. For simplicity, the neutrosophic demand is converted into a representative demand value for computational purposes. In this numerical illustration, the representative demand values are considered as $D = 60, 80,$and 100units per cycle.

Let the ordering cost per order be

K = 30

and the holding cost per unit per unit time be

h = 4.

The optimal order quantity is determined using the EOQ expression

$$Q^* = \sqrt{\frac{2DK}{h}}$$

Substituting the values of $K$and h,

$$Q^* = \sqrt{\frac{2D(30)}{4}} Q^* = \sqrt{15D}$$

Thus, the optimal order quantity depends on the demand level D.

For different demand values, the corresponding optimal order quantities are calculated as follows.

For $D = 60$

$$Q^* = \sqrt{15 \times 60} = \sqrt{900} = 30$$

For $D = 80$

$$Q^* = \sqrt{15 \times 80} = \sqrt{1200} \approx 34.64$$

For $D = 100$

$$Q^* = \sqrt{15 \times 100} = \sqrt{1500} \approx 38.73$$

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Table 1. Optimal Order Quantity for Different Demand Levels

Demand (D)	**Optimal Order Quantity (Q^*)**
60	30.00
80	34.64
100	38.73

Table 1 shows that the optimal order quantity increases as the demand level increases. This result is consistent with inventory theory, where higher demand requires larger replenishment quantities to minimize ordering and holding costs.

6. Results and Discussion

The results obtained from the numerical example indicate that the optimal order quantity increases with the increase in demand level. This behaviour is consistent with classical inventory theory.

The proposed model incorporates neutrosophic representation of demand, which allows uncertainty and indeterminacy in demand estimation to be captured. This provides a more flexible framework compared with purely deterministic models.

The numerical results demonstrate that the model can effectively determine optimal inventory policies even when demand information contains uncertain or indeterminate elements.

7. Conclusion

In this chapter, an inventory model incorporating neutrosophic demand has been presented. The model extends the classical inventory framework by representing demand through truth, indeterminacy, and falsity components, which allows uncertainty to be handled more effectively.

The mathematical model was formulated to determine the optimal order quantity that minimizes the total inventory cost. A numerical example was provided to illustrate the applicability of the proposed model. The results show that the model can determine optimal ordering decisions for different demand levels in a neutrosophic environment.

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