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Research article

A distribution-free newsvendor model considering environmental impact and shortages with price-dependent stochastic demand

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Abstract: In today's competitive and volatile market, demand prediction for seasonal items is a challenging task. The variation in demand is so quick that the retailer cannot face the risk of understocking or overstocking. Unsold items need to discarded, which has environmental implications. It is often difficult to calculate the effects of lost sales on a firm's monetary values, and environmental impact is not a concern to most businesses. These issues concerned with the environmental impact and the shortages are considered in this paper. A single-period inventory mathematical model is formulated to maximize expected profit in a stochastic scenario while calculating the optimal price and order quantity. The demand considered in this model is price-dependent, with several emergency backordering options to overcome the shortages. The demand probability distribution is unknown to the newsvendor problem. The only available demand data are the mean and standard deviation. In this model, the distribution-free method is applied. A numerical example is provided to demonstrate the model's applicability. To prove that this model is robust, sensitivity analysis is performed.

Keywords: newsvendor problem; distribution-free approach; stochastic price-dependent demand; supply chain management; partial backlogging

1. Introduction

It is challenging to determine the exact demand for the seasonal items; because of the stochastic nature retailers face two types of situations: overstocking and understocking. If they order more, they face an overstocking issue, which results in salvaging the additional items. Those items salvaged or discarded possess hazardous chemical properties and create environmental concerns. Shortages destroy the company's brand image and customer goodwill. Some customers wait for the backlog while the remaining are lost, which results in the loss of additional sales. This paper describes how to calculate the stochastic price-dependent demand with the order quantity by using a newsvendor model. Shortages are allowed and partially backlogged with emergency replenishment schemes. Environmental pollution is increasing rapidly, which is very harmful to nature. There are many reasons behind this, and one main reason is hazardous waste material, which is not getting due importance in supply chain management (SCM). Governments and consumers increasing awareness encourages firms to pay attention to the environmental impact of hazardous waste material. This paper develops a mathematical model, considering stochastic price-dependent demand, to calculate the optimal price and order quantity while maximizing profit.

The faster growth of technology and innovation has accelerated the product development process. It has many advantages to the customer, while it creates severe problems for a product with a shorter selling season. These products include fast-moving consumer goods, mobile phones, personal computers, apparel, and other seasonal items. Newsvendor models can be applied to insurance schemes and healthcare finance schemes [1, 2]. The newsvendor model is most relevant to dealing with the short product life cycle. Those businesses selling seasonal items face volatile demand. Access order causes loss due to salvaged if fewer items are ordered shortage occurs. This newsvendor model is applied with price-dependent stochastic demand so that expected profit can be calculated simultaneously by calculating the optimal price and order quantity.

The following research questions are formed by considering the literature review gap:

- In a price-dependent stochastic environment, how much should the newsvendor order?
- How to overcome the situation with no historical data on demand?
- What is the impact of unsold items on the model's profit, and how could the wastage be reduced?
- What is the impact of shortages on the model?
- What is the impact of contingency plans on the total profit of the model?

In this model, shortages are allowed and partially backlogged. The exponential backordering function is used for partial backlogging. To backlog shortages, emergency backordering options are considered in this model that are higher than the standard price. If the stock remains after the season, it is salvaged with a constant salvage price that is lower than the purchasing price. A shortage occurs for the following reasons: unavailability of raw material, machine breakdown, and many other reasons. In seasonal items, for example, during COVID-19, shortages are caused by a sudden increase in demand for masks, sanitizers, and vaccines. Firms want to maintain market share, so they must compensate for the shortfall with available resources. Due to unsatisfied shortages, firms lose their brand image and potential customers. If shortages are partially backlogged, the newsvendor incurs a backordered cost that is usually higher than the actual price. That backordering cost depends on the time duration of backlogging. In this model, shortages are partially backlogged, with different replenishment schemes, and their outcomes are observed.

In Section 2, a literature review is presented. Section 3 contains a model description with the problem definition assumptions and notation. The mathematical model is developed in Section 4. The solution methodology is provided in Section 5. To validate the model, numerical experiments and sensitivity analyses are presented in Section 6. In Section 7 the managerial benefits are provided. Finally, the conclusion and future recommendations are presented in Section 8.

2. Literature review

2.1. Newsvendor model

The newsvendor problem has a long history, but this problem is still of interest because of the innovation and faster growth of technology. Technologies are changing rapidly, and those products lose their value so fast. An example of this is the sudden decline in the prices of cell phones, personal computers, and laptops with the launch of new products [3, 4]. The newsvendor problem has gained significant attention over the past three decades. The detailed literature related to the newsvendor model and its extensions was described by Petruzzi and Dada [5], Khouja [6], and Qin et al. [7] in review papers. Heydari and Momeni [8] developed the newsvendor model in the two-echelon retailing channel, where they consider a single wholesaler and two non-competitive retailers to satisfy the consumer demand. The coalition aimed to get the optimal quantity discount from the wholesaler in three scenarios in their paper.

2.2. Price-dependent stochastic demand

Traditionally, the exogenous price was considered in the newsvendor model, in which there was no control of the newsvendor. This type of demand exists in competitive markets, where the buyers solely decide on price. However, in reality, retailers adjust the price by making a variation in the actual demand. Following are the pioneering papers: Whitin [9], Mills [10], Karlin and Carr [11] who investigated demand process effects on the sellers pricing and ordering decisions. Within [9] had given the optimal condition within two models, i.e., for the newsvendor model and economic order quantity (EOQ). He provided the rectangular demand distribution with the closed-form solution of the newsvendor model. Mills [10] considered additive price-dependent demand with a random term ϵ, price independent, i.e., $X = \gamma(p)+\epsilon$, where $\gamma(p)$ is the mean and market price-dependent demand. Chen et al. [12] developed a stochastic price-dependent newsvendor model in a competitive environment.

Qin et al. [7] has revived the newsvendor problem with a focus on customer demand modeling, buyer risk profiles, and supplier cost. Furthermore, they investigated the impact of market price, effort, and quantity on demand. Afshar-Nadjafi [13] investigated the sale announcement in a single-period inventory model for perishable items while considering the known expiry date and stochastic demand. They further explained that a special cell before expiration at a particular time reduces the damage caused by expired products. Kumar et al. [14] developed a model in which the demand was advertising dependent, and they considered carbon emission costs for the manufacturer's and supplier's holding and degrading costs. Sarkar et al. [15] discussed a complex multi-stage defective production system where the demand was selling price-dependent. Choi et al. [16] investigated the effects of intelligent service for an online-to-offline supply chain where demand was selling price-dependent.

2.3. Shortages

Shortages create many problems for the firms, such as brand image loss and revenue loss. Some customers wait for late delivery, and some cancel their orders. Those canceled orders are a loss to the firms. That unsatisfied demand can be backlogged. Following are some related studies that define shortages that can be backlogged, or it is lost sales. Montgomery et al. [17] were the pioneers that defined a part of shortages that were backlogged, and the remaining was the lost sales. Wee [18] used Weibull distribution for deteriorating products in a deterministic inventory model considering partial backlogging, pricing, and quantity discounts. Lodree Jr. [19] investigated the shortages in the newsvendor model and classified them into backorders and lost sales. In their model, backlogged products were replenished with emergency procurement schemes without waiting for the next scheduled delivery, as in the case of many continuous review models. They further derived the optimal solution for exponential demand distribution. The study of lead time, backorder cost, and lost sales due to shortages were done by Chang and Lo [20] with the continuous and discrete lead time demand, and they have found the local optimal solution. Brito and de Almeida [21] developed a model where the waiting time function decreased exponentially, and they partially backlogged the demand in their model. A loss averse newsvendor model was considered by Xu et al. [22] with backordering, and they calculated the optimal order quantity.

The spectral risk was considered by Li and Ou [23] with an emergency replenishment scheme and backordering cost. They developed a policy for calculating the optimal ordering quantity for complementary products in a newsvendor framework. In their model, the firms have the opportunity to buy the product through the emergency channel during the season at a moderately higher cost than the regular cost. Taleizadeh et al. [24] examined the disruption in the inventory management framework on the supplier side for continuous cycle and time-dependent demand cycles. They proved the convexity of the model and calculated the optimal decisions. However, their model was limited to a single objective of profit maximization. Maihami et al. [25] considered the deteriorating item SCM and studied the pricing and inventory problem with partially backlogged shortages and greening investment. Mahapatra et al. [26] studied the three continuous review EOQ models for time-dependent deterioration utilizing preservation technology. They allowed shortages with a total backorder and incorporated promotional efforts. Tayyab et al. [27] developed a sustainable model considering economic, social, and environmental aspects in a multi-stage production mode. Shortages were allowed in their model and met with the planned backorder. Sarkar et al. [28] studied an inventory model for shortages which was solved by an artificial neural network (ANN) with multithreading. They proved that the proposed method gave a better result than other metaheuristics approaches.

2.4. Distribution-free approach

Demand distribution estimation is a tough job in seasonal item SCM. Most of the time, information on on-demand distribution is unavailable to the manager or needs enormous funds to estimate the real-time demand distribution. For such a situation, Scarf [29] first introduced the distribution-free (DF) approach, where only the demand data mean and standard deviation ware required. In Scarf's rule, the worst distribution point is at two points. However, the Scarfs rule was compact and challenging to use for managers. Gallego and Moon [30] simplified Scarf's rule, maling it is easy to understand and require the demand data mean and standard deviation. Abad [31] considered the backlogging in a newsvendor model to calculate the optimal quantity; however, he did not consider backlogging and lost sales cost because, in real time, these parameters are difficult to estimate. In their mode, backlogging demand decreased as waiting time increased. He and Wang [32] analyzed the vendor buyer inventory decision in an uncertain unit profit environment. They further analyzed the consumer evaluating process with the help of a mathematical model to understand the cost-benefit association and its effect on consumer inventory decisions.

2.5. Environmental impact

According to recent research, consumers are more interested in buying items from companies that consider environmental policies and sustainability characteristics. Hong and Guo [33] analyzed the cooperation contracts in a green items supply chain and examined their environmental performance. Accenture's study found that only one in ten companies effectively manages their carbon footprint in the supply chain. According to existing research, more than 80% of interviewers prefer item greenness while making buying decisions this [33]. The green option helps companies market their items better and raises awareness concerning their products [34]. Their study also shows economic benefits for both vendors and buyers in a green supply chain. Govindan et al. [35] published a review paper on social sustainability in supply chain. Chan et al. [36] studied the environment-related taxes in the newsvendor model, and they state that there is an enormous amount of carbon emission from the fashion industry. Shi et al. [37] emphasized the environmental impact in the retailer product development process. Habib et al. [38] proposed an animal fat-based biodiesel supply chain model that reduces the system's total cost and accounts for both disruption and operational risks. Shen et al. [39] compared green and non-green items with service-level constraints, emphasizing the effects of big data on increasing profits and lowering environmental costs. Yadav et al. [40] formulated a pollution-controlled flexible production system. Furthermore, they addressed environmental concerns by controlling by-products of the production system under three different pollution control schemes.

The rapidly changing technology's next focus is to trace and track the issues related to the supply chain. As Tan et al. [41] presented a framework for green logistics based on blockchain technology to make sustainable supply chain operations. Furthermore, they integrated the Internet of Things and big data into their framework. Kumar et al. [42] used the context of the food supply chain to highlight the design and implementation challenges of blockchain and emphasized the use of blockchain technology. Liu et al. [43] proposed the fusion application environment of big data and blockchain with one retailer and one producer in a green agri-food supply chain. They highlighted the benefits of using big data and blockchain, and they studied the issues of investment decisions and coordination policies in a green agri-food supply chain. Sarkar et al. [44] developed a three-echelon supply chain model for biodegradable products. They established three different transportation paths for biodegradable products within the supply chain. Sana [45] compared the green and non-green practices for a newsvendor inventory model where governments are giving subsidies and reducing the taxes on green products to the corporate socially responsible firms. Kugele et al. [46] developed a smart production system to control carbon ejection and solved the model by using geometric programming. Sarkar et al. [47] developed a decision support system (DSS) within an emissions-controlled flexible production system for substitutable products. Their model aimed to reduce carbon emissions from the flexible manufacturing system. Moon et al. [48] developed a mathematical model for emissions-controlled production system with degree of difficulty two. They found an unique solution of heterogeneous combination of variable-constrains using geometric programming. In Table 1, the literature concerning this model is described with the appropriate keywords.

Table 1. Literature review table.

Article	SCM	Price dependent demand	Partially backlogged	DF approach	Environmental impact
Abad [49]	✓	✓			
Alaei and Setak [50]	✓			✓	
Pal et al. [51]	✓		✓		
Abdel-Aal et al. [52]	✓		✓		
Chen et al. [53]	✓	✓			
Chan et al. [36]	✓				✓
Hu and Su [54]	✓	✓			
Padiyar et al. [55]	✓				
Sarkar et al. [56]	✓			✓	
Hong and Guo [33]	✓				✓
Shi et al. [57]	✓				
Li and Ou [23]	✓		✓		
Govindarajan et al. [58]	✓			✓	
Fan et al. [59]	✓				
Jadidi et al. [4]	✓	✓			
Sarkar et al. [60]	✓				
Maihami et al. [25]	✓	✓	✓		✓
Bi et al. [61]	✓				
Hovelaque et al. [62]	✓	✓			
This Study	✓	✓	✓	✓	✓

3. Model description

3.1. Problem definition

The newsvendor model has been studied in many directions, but so far, the researchers have focused on minimizing cost or maximizing profit. However, environmental awareness and government regulations have prompted firms to consider environmentally friendly products. Shortages are the main concern for the newsvendor. Some customers wait for the delivery while others balk. In the newsvendor model, estimating the exact distribution of demand is hard, or many resources and funds are needed to predict the correct demand. A DF approach is used in this model to manage uncertain seasonal demand. To maximize the expected profit while considering environmental impact, quantity and price are calculated in this model.

3.2. Assumptions

1) The environmental impact is considered for the maximization of the expected profit in this SCM model.

2) A fixed cost is considered for items to be discarded in the newsvendor model to reduce the environmental impact of hazardous materials.

3) Shortages are considered with partial backlogging, and lost sales show the proportion of unsatisfied customers.

4) Shortages are partially backordered with backordering price.

5) Demand is price-dependent and stochastic and does not follow a specific distribution. While making a decision, the newsvendor is aware of the mean and variance of demand.

3.3. List of notation

Indices		
i	selling period index	$(i = 1, 2, 3, ..., n)$
j	contingency plan index	$(j = 1, 2, 3, ..., m)$
Decision variables		
p	unit selling price (\$/unit)	
q	quantity (units)	
Parameters		
d	price-dependent stochastic demand (units)	
s	salvage value (\$/unit)	
c	ordering cost per item (\$/unit)	
X	random demand	
α	historical correlation data	
β	fraction of regularly satisfied demand	
τ	replenishment waiting time	
b_j	backorder cost concerned with the emergency replenishment option v_j (\$/unit)	
$\gamma(p)$	deterministic demand in the season, dependent on price (units)	
l	a lost sale due to customer balking (\$/unit)	
k_j	constant related to emergency scheme s_j	
v_j	contingency plan	
μ	demand expected value	
σ	standard deviation of demand	
z	price sensitivity	
y	risk-less demand (deterministic demand) (units/unit time)	
$\Pi(q, p)$	expected profit of SCM (\$)	

4. Mathematical modeling

This section commences with presenting basic formulas concerning the newsvendor model. Furthermore, a detailed explanation of the newsvendor model with an exponential backordering function is described. The profit and environmental functions are explained in this section.

4.1. Proposed model

The newsvendor model is formulated with optimal ordering and pricing decisions under uncertain demand. The items with a short selling season are considered. A single product unit cost is c, and the price per item is p. The order of q items is placed before the beginning of the selling period with the stochastic price-dependent demand d. The demand $d(p, X) = \gamma(p) + X$ consists of two parts. The first part $\gamma(p)$ is the price-dependent deterministic demand, and the second part is independent of the price, and it is a random demand (X). These types of demand are common in the literature considered by [63]. Items leftover after the sales season are sold at a salvaged value s. The nature of stochastic price-independent demand X is additive. In the selling season, the price-independent demand X is a random variable with a probability density function (PDF) $f(X)$ and a cumulative distribution function (CDF) $F(X)$ with the mean μ_i and standard deviation σ_i.

Profit maximization is the main objective of every firm, which can be achieved by calculating the optimal ordering quantity and price. Furthermore, this study considers the environmental impact of profit maximization. The cost is subtracted from the revenue in this model to calculate the profit. The revenue is generated by selling the product at a price p, and the remaining items are discarded at a constant salvage cost s. If demand during the season is less than the order quantity. In that situation, the generated revenue is equal to $pd(p, X)$, and leftover items are salvaged. Else, the revenue is equal to pq, and the expected revenue generated is given as $pE(min(q, d))$. The purchasing cost is expressed as cq for q products. The newsvendor basic profit function is shown as

$$\Pi(q, p) = \begin{cases} (p - c)q + (p - b_j)\beta(d - q)^+ - l(1 - \beta)(d - q)^+ & if d \geq q \\ pd - cq - s(q - d)^+ & if d < q \end{cases}$$

The typical newsvendor model is established to maximize profit or minimize cost. The competition in the market has forced the newsvendor to consider other parameters, such as their social role and brand image enhancement. The company's social position depends on environmental policies, and its brand image could be improved if the shortages are satisfied immediately with robust policies. To solve the newsvendor model, an approach is required where not only profit is taken into consideration while selecting order quantity. The newsvendor has to think out-of-the box in multiple dimensions when determining q. Therefore, we have developed this model, where environmental impact is considered while selecting the order quantity.

4.2. Environmental impact

Rapidly changing technology has forced customers to consider new and innovative products. Therefore, companies are developing their products so fast, especially seasonal items. If those products are not discarded properly, they can harm the environment in many ways. Strict regulations from various countries and customer awareness regarding the environment have forced companies to consider the environmental impact in their decision-making process. Therefore, in this study, environmental impact is also considered with profit maximization. The effect of pollution caused by scrapping unsold items is considered in this model. The scrap includes hazardous and toxic materials that harm the environment badly. Such products include mobile phones, computers, masks, plastic bags, etc. If the extra stock is minimized, it can reduce the risk of environmental impact due to unsold products.

The emission from unsold items harms the ecosystem and has hazardous effects on the environment.

Therefore, a newsvendor is considered who is willing to reduce the environmental impact due to unsold items. The recycling network and reverse logistic is not considered in this model. It is further assumed that the environmental effects are directly proportional to the leftover products to be scrapped. This attribute outcome can be seen in the below equation.

$$EN(q) = \begin{cases} 0 & for\ d \geq q \\ w(q-d) & for\ d < q, \end{cases}$$

where w has a constant value concerning the environmentally hazardous chemical or physical substance to be scrapped. The value of w is estimated from item particularities and the disposal site. From the above equation, it is clear that environmental impact is not dependent on the k_j value. When the newsvendor faces shortages, there is no inventory to discard, which is the reason that this only depends on q.

4.3. Emergency replenishment option

In many businesses, stockout is the leading cause of customer loss, because customers select some other products in this competitive business scenario. Stockout negatively affects customer goodwill, profit, brand image, and market share. Hence, before the selling season begins, the newsvendor commits that, if stockout occurs, the quantity q will be backordered at a particular contingency plan $V = \{v_1, v_2, ..., v_m\}$ of a limited set of n emergency replenishment plan.

In this model, emergency replenishment plans are designed such that they must take less procurement lead time relative to original orders. Reducing the lead time will certainly increase the ordering cost because of overtime, faster delivery methods, extra production runs, and emergency purchases. The backordring cost is usually high, but customer loyalty is more important. Here, the contingency plan v_j consists of two parameters: the first is the time coefficient $k_j \epsilon K = \{k_1, k_2, ..., k_m\}$, and the second is associated with the bakordering cost. The backordring cost is defined as the per-unit cost that the company has to pay for the emergency plan v_j, which may be utilized to minimize lead time with the coefficient k_j, in the range $0 < k_j < 1$. Accordingly, if the newsvendor requires a shorter lead time, they must pay higher backorder costs b_j. The backordering cost b_j affects the ordering lot q. The ordering decision varies based on v_j. Here, v_j has a discrete value, and q is continuous variable.

4.4. Demand backlogging behavior

The newsvendor model is considered, where shortages are fulfilled with partial backlogging via emergency replenishment. By utilizing the notation elaborated in [17, 21] the amount of shortages is denoted as β, which is the probability of backlogging a single customer in the stockout period, or the fraction of demand satisfied [19, 64]. The fraction of shortage β is considered as a known parameter. Although, in some articles, β is considered a parameter of replenishment waiting time τ when shortages occur. The parameter β is considered as a strictly decreasing function of τ in this model. Furthermore, the uncertainty associated with the emergency lead time is not considered [19, 31]. The customer's behavior concerning the replenishment waiting time is modeled and shown as follows [64]:

$$\beta(\tau) = e^{-\alpha\tau}. \tag{4.1}$$

In the above equation, α is statistically generated by the newsvendor based on historically correlated data and a β is the function of the shortage size. Furthermore, to get the general interpretation during emergency replenishment, τ is directly proportional to the demand subtracted by the quantity $(d-q)$ and shortage units [19]. Accordingly, following is the replenishment waiting time as

$$\tau_j = k_j(d-q). \tag{4.2}$$

In the above Eq (4.2), k_j is a constant parameter associated with the emergency plan v_j. From Eqs (4.1) and (4.2), the amount of unmet demand in the backlogging is described by the shortage size function [19] as

$$\beta(d-q)^+ = e^{-\alpha k_j((d-q)^+}. \tag{4.3}$$

4.5. DF approach

In this model, no assumption is made for the demand d probability distribution, as the only available data to the newsvendor is the mean and standard deviation of the demand. The lemmas [30] are used, further modified by Ullah et al. [63]
Lemma (i)

$$E(d-q)^+ \leq \frac{1}{2}(\sqrt{\sigma^2 + (q-\mu-\gamma)^2} - (q-\mu-\gamma))$$

Lemma (ii)

$$E(q-d)^+ \leq \frac{1}{2}(\sqrt{\sigma^2 + (q-\mu-\gamma)^2} - (\mu+\gamma-q)).$$

Furthermore, this inequality's upper bound is tight [63]. The profit function with backordering is as follows

$$\Pi(v_j, q, p) = p(\min(q, d)) - cq + \beta(d-q)^+(p-b_j) - (1-\beta)l(d-q)^+ + s(q-d)^+. \tag{4.4}$$

As we know that

$$\min(q, d) = d - (d-q)^+$$

and

$$(q-d)^+ = (q-d) + (d-q)^+.$$

The price-dependent stochastic demand function can be described as

$$d = d(p, X).$$

Expected demand is equal to

$$E(d) = \gamma(p) + \mu_i \geq 0.$$

Price-dependent deterministic demand can further be divided into market share and the product of price sensitivity and price.

$$\gamma(p) = y - pz. \tag{4.5}$$

By using the lemma and Eq (4.1), the demand backordering equation becomes

$$\beta(d-q)^{+} = e^{-\alpha * k_j(\frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2}-(q-\mu-\gamma)))}. \tag{4.6}$$

By utilizing lemmas (i) and (ii) and putting in all of the values from the above equations and further simplification, the final equation for newsvendor profit is

$$\begin{aligned}\pi(v_j, q, p) = {} & (p+s)(\mu+\gamma) - (c+s)q - (s+p) * \frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2} - (q-\mu-\gamma)) \\ & -l(1-e^{-\alpha k_j(\frac{1}{2}\sqrt{\sigma^2+(q-\mu-\gamma)^2}-(q-\mu-\gamma))}) * \frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2} - (q-\mu-\gamma)) \\ & +(p-b_j)e^{-\alpha * k_j(\frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2}-(q-\mu-\gamma)))} * \frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2} - (q-\mu-\gamma)).\end{aligned} \tag{4.7}$$

The below equation represents the environmental impact, and it is the simplified version of the attribute equation after utilizing the lemmas:

$$EN = (w(q-(\mu+\gamma) - \frac{\sqrt{\sigma^2+(q-\mu-\gamma)^2} - (q-\mu-\gamma)}{2}). \tag{4.8}$$

The final simplified equation representing the profit function with environmental impact cost is

$$\begin{aligned}\Pi(v_j, q, p) = {} & (p+s)(\mu+\gamma) - (c+s)q \\ & -(s+p) * \frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2} - (q-\mu-\gamma)) \\ & +(p-b_j)e^{-\alpha * k_j(\frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2}-(q-\mu-\gamma)))} * \frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2} - (q-\mu-\gamma)) \\ & -l(1-e^{-\alpha k_j(\frac{1}{2}\sqrt{\sigma^2+(q-\mu-\gamma)^2}-(q-\mu-\gamma))}) * \frac{1}{2}(\sqrt{\sigma^2+(q-\mu-\gamma)^2} - (q-\mu-\gamma)) \\ & -(w(q-(\mu+\gamma) - \frac{\sqrt{\sigma^2+(q-\mu-\gamma)^2} - (q-\mu-\gamma)}{2}.\end{aligned} \tag{4.9}$$

5. Solution methodology

This study develops a mathematical model for the newsvendor with partial backlogging and price-dependent stochastic demand. A closed-form solution is achieved while applying a distribution-free approach. To show that the model is globally optimal, the below steps are used. The optimal order quantity and price are calculated for the supply chain model. Furthermore, this model offers various emergency replenishment schemes with varying backordering rates. The following steps are used in the solution procedures of the proposed mathematical model.

5.1. Solution algorithm

Step 1 Consider all input parameters and assign them a value.

Step 2 Determine the partial derivatives of the objective function with respect to q and p, as shown in Eqs (5.1) and (5.2), and put these all equal to zero to fulfill the necessary conditions. $\frac{\partial U(p,q)}{\partial_q} = 0$, $\frac{\partial U(q,p)}{\partial_p} = 0$

Step 3 Obtain the optimal price p^* and order quantity q^* as a closed-form solution by simultaneously solving the partial derivatives from Step 2.

Step 4 Put q^* and price p^* from Step 3 in the profit function to get the closed-form solution of the maximum expected profit (Π) of the supply chain.

Step 5 To find the critical points from Step 4, check the sufficient condition for optimality; if Π^* satisfies (ii), the model has a local maximum:
(i) $Det(H_{22}) > 0$ and $\frac{\partial^2 U}{\partial q^2} > 0$, the critical point is a local minimum.
(ii) $Det(H_{22}) > 0$ and $\frac{\partial^2 U}{\partial q^2} < 0$, the critical point is a local maximum.
(iii) $Det(H_{22}) < 0$, the critical point is a saddle point.

Step 6 Verify that U^* is a local maximum by checking the sufficient condition for optimality.

Prove the sufficient condition of the model the determinant of $(DetH_{22}) > 0$ and $\frac{\partial^2 U}{\partial q^2} < 0$:

$$H_{22} = \begin{vmatrix} \frac{\partial^2 E(U)}{\partial q^2} & \frac{\partial^2 E(U)}{\partial q \partial p} \\ \frac{\partial^2 E(U)}{\partial p \partial q} & \frac{\partial^2 E(U)}{\partial p^2} \end{vmatrix} > \quad 0.$$

5.2. Optimal policies

For the necessary and sufficient condition of the total expected profit for q and p, the first-order derivatives are calculated as shown below:

$$\frac{\partial U(v_j,q,p)}{\partial_q} = \frac{1}{4U}(\alpha(b-p)k_i(\gamma+\mu-q+U)^2\left(-e^{-\frac{1}{2}\alpha k_i(\gamma+\mu-q+U)}\right) + 2(b-p)(\gamma+\mu-q+U)$$
$$e^{-\frac{1}{2}\alpha k_i(\gamma+\mu-q+U)} - 4cU + \alpha l k_i(\gamma+\mu-q+U)^2 e^{-\frac{1}{2}\alpha k_i(\gamma+\mu-q+U)} + 2l(\gamma+\mu-q+U)$$
$$\left(1-e^{-\frac{1}{2}\alpha k_i(\gamma+\mu-q+U)}\right) + 2(p+s)(\gamma+\mu-q+U) + 2w(\gamma+\mu-q-U) - 4sU). \tag{5.1}$$

To simplify the above equation, the parameter U is used as follows:

$$U = \sqrt{(\gamma+\mu-q)^2+\sigma^2}.$$

The first order derivative for price is calculated as

$$\frac{\partial U(v_j,q,p)}{\partial_p} = \frac{1}{2}\left(\sqrt{(-\gamma-\mu+q)^2+\sigma^2}+\gamma+\mu-q\right)e^{-\frac{1}{2}\alpha k\left(\sqrt{(-\gamma-\mu+q)^2+\sigma^2}+\gamma+\mu-q\right)}$$
$$+\frac{1}{2}\left(-\sqrt{(-\gamma-\mu+Q)^2+\sigma^2}-\gamma-\mu+q\right)+\gamma+\mu. \tag{5.2}$$

6. Numerical experiment

This section includes a numerical study to demonstrate the newsvendor model. A computer tool is utilized to get the result of the numerical experiment.

This model is developed considering seasonal item supply chains such as mobile phones. These items have a short life cycle; they are quickly replaced with an upgraded version. The mobile phone industry is very competitive, and to stay competitive, continuous development is being performed.

A numerical experiment is performed to show the model validity, and the following data are considered [21, 28, 63]. The model is not restricted to only that particular case or data. The demand parameters $\mu = 3000$, $\sigma = 200$, $y = 300$ units/period, and $z = 12$ are considered. The cost parameters are as follows: purchasing cost (c) = 150 \$/unit, salvage value (s) = 60 \$/unit, lost sales cost (l) = 90 \$/unit, $\alpha = 0.05$, and waste disposal cost (w) = 0.9 \$/unit. The demand backlogging behavior is shown in Table 2.

Table 2. Emergency replenishment plans.

Option	k_j	b_j
v_1	0.95	160
v_2	0.70	205
v_3	0.60	250
v_4	0.50	290
v_5	0.40	350
v_6	0.30	425
v_7	0.25	475

The optimum values of quantity and price to achieve the maximum profit for every set of v_j is calculated. The v_j set includes seven values of b_j and k_j. These results are presented in Table 3.

Table 3. Optimum values for replenishment schemes of newsvendor model.

Options	q^*	$E(\Pi)$	p^*
v_1, q^*, p^*	774.76	11,357.4	207.57
v_2, q^*, p^*	775.22	11,473.1	207.67
v_3, q^*, p^*	773.92	11,460.4	207.72
v_4, q^*, p^*	771.33	11,346.4	207.79
v_5, q^*, p^*	765.46	10,736.4	207.85
v_6, q^*, p^*	755.86	8829.34	207.99
v_7, q^*, p^*	750.08	6638.99	208.19

To show the price change effect on the profit of the model, 2D plots are shown in Figure 1. The effect of order quantity versus total profit is portrayed in Figure 2. A 3D plot of the combined effect of price and quantity on profit is shown in Figure 3.

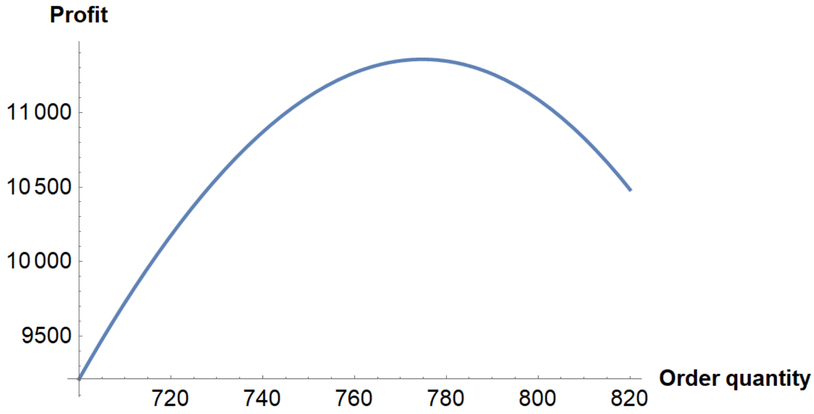


Figure 1. Profit versus order quantity.

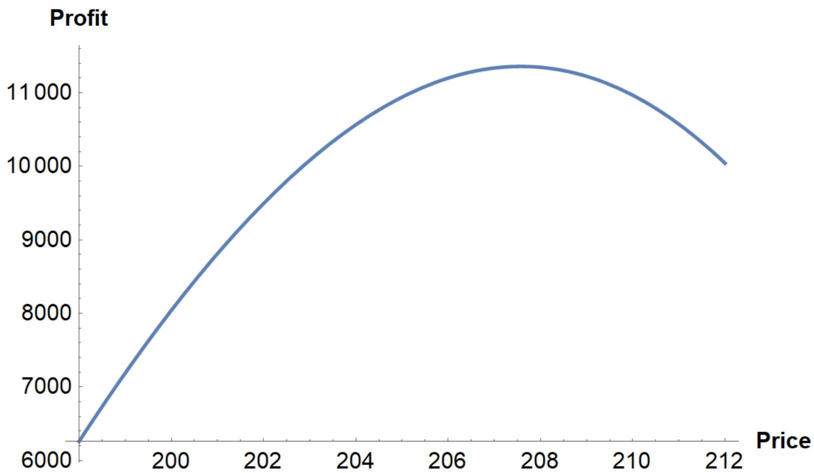


Figure 2. Profit versus price.

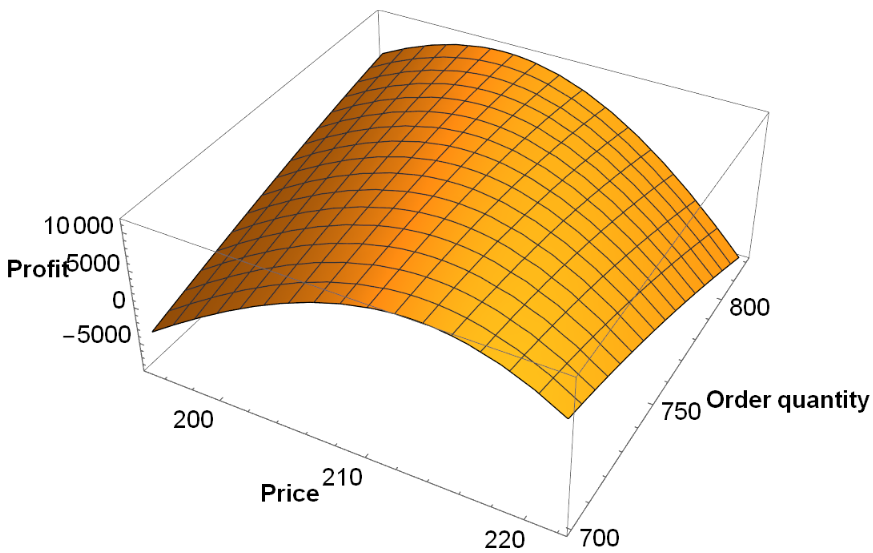
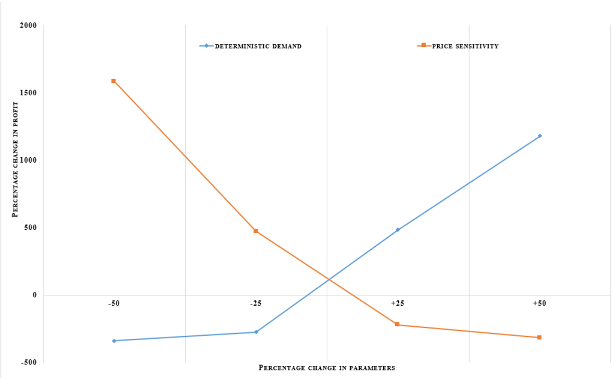
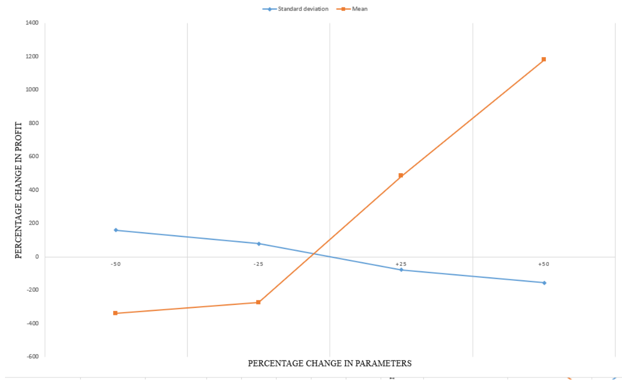


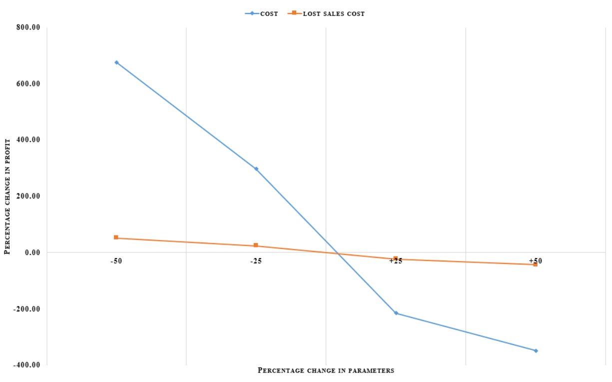
Figure 3. 3D representation of profit with order quantity and price.



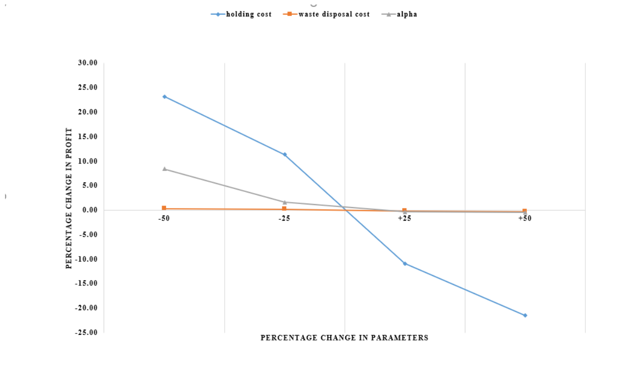
(a) Deterministic demand and price sensitivity



(b) Mean and standard deviation of demand



(c) Purchasing cost and lost sales value



(d) Cost parameters

Figure 4. Graphical illustration of sensitivity analysis within the range of −50% to +50%.

6.1. Sensitivity analysis

A sensitivity analysis of the major parameters and demand parameters is used to validate this model. Graphical representations of the key parameters and demand parameters are shown in Figure 4. The numerical outcomes of the sensitivity analysis are presented in Tables 4 and 5 with a detailed analysis of the key parameters summarized as follows.

1) Among all of the essential parameters, the cost parameter is the most sensitive. In this model, by reducing the cost by 50%, the total profit of the system increases by 676.29%. Reducing 25% increases profit by 296.80%, and if we increase it by 25%, profit decreases by 215%. Similarly, a 50% increase in cost reduces the total profit by 348.4%. From the conclusion of the cost analysis, it can be concluded that, if the price goes down, it has a magnificent effect on profit compared to an increase.

2) The lost sales cost is almost similar to the symmetrical effect on the model's profit. The 50% decrease accounts for a 51.4% increase in the profit. Moreover, a 25% increase and decrease led to a 24.46% increase and 22.52% decrease in the profit, respectively. Furthermore, increasing 50% reduces profit by up to 43.48%. Analysis of the cost of lost sales shows that the effect of cost reduction outweighs the increase.

3) The salvage value has a balanced effect on the profit increase and decrease; a 50% decrease of the

salvage value accounts for 23.17% increase in profit; similarly, a 50% increase reduces the total profit by 21.49%.

4) The environmental cost of waste disposal has minimal impact on the model's profit. The impact is symmetrical, as a 50% decrease and increase reduces and increases the profit by 0.33%, respectively.

5) The parameter α is obtained based on historical correlated data. It increases the profit by 8.3% if the value is decreased by 50%, then, there is a 50% increase that yields a 0.47% decrease. It suggests that it has a greater positive effect than negative effect.

Table 4. Key parameters sensitivity analysis.

Parameter	Variation in value	Change in total expected profit
c	−50	+676.29
	−25	+296.80
	+25	−215.00
	+50	−348.46
s	−50	+23.17
	−25	+11.35
	+25	−10.93
	+50	−21.49
l	−50	+51.40
	−25	+24.46
	+25	−22.52
	+50	−43.48
w	−50	+0.33
	−25	+0.17
	+25	−0.17
	+50	−0.33
α	−50	+8.39
	−25	+1.62
	+25	−0.38
	+50	−0.47

The detailed sensitivity analysis of four demand parameters is as follows.

(1) A 50% increase and decrease in the standard deviation value have a balanced effect on the total cost, with a slight variation in the increase in the standard deviation value. The total profit is increased by 160.5% with a reduction of the standard deviation by 50%; however, a 155.09% decrease occurs with a 50% increase in standard deviation value.

(2) The mean has an asymmetric effect in this model. A reduction of 50% accounts for a 338.27% decrease in profit, and with the 50% increase, the profit drastically jumps by 1179.32%.

(3) A change in market share or riskless market demand has an effect that is similar to the symmetrical impact on the total profit of the model. A 50% reduction in profit reduces it by 71.84%, and a similar increase in profit occurs with a 50% increase in value.

(4) The price sensitivity is the most sensitive parameter among all of parameters, and it possesses an asymmetrical effect on the model's profit. Increasing price sensitivity up to 50% reduces the profit by 317.50%, and a 50% decrease in value accounts for a 1589.83% increase in profit.

Table 5. Demand parameters sensitivity analysis.

Parameter	Variation in value	Variation in expected profit
σ	−50	+160.05
	−25	+78.94
	+25	−77.84
	+50	−155.09
μ	−50	−338.27
	−25	−274.94
	+25	+485.07
	+50	+1179.32
y	−50	−71.84
	−25	−36.97
	+25	+39.07
	+50	+80.24
z	−50	+1583.93
	−25	+473.70
	+25	−221.37
	+50	−317.50

7. Managerial insights

In SCM, the focus is on maximizing profit or minimizing costs. However, other economic values, such as environmental impact, are not considered. This model considers waste disposal cost that reduces the environmental impact concerning waste. The sensitivity analysis shows that it has a minimal impact on the total profitability of the model. The government regulation has diverted the thinking of the managers from profit to sustainable SCM. The aim is profit maximization, but environmental policies are required to accomplish that. The customer's awareness of the environmental impact makes it necessary for the manager to focus on this issue. This model considers stochastic demand, which needs only the mean and standard deviations of the demand. The DF approach saves many funds that would otherwise be spent on real-time data collection. The goal of every manager is to meet customer demand, but sometimes shortages occur due to the uncertain nature of demand. Partial backlogging is allowed in this model to address the shortage, and various emergency replacement policies have been introduced.

8. Conclusions

This newsvendor model aimed to maximize expected profit with the environmental impact. The pricing and inventory decisions related to order quantity were made jointly. In this model, price-dependent stochastic demand of additive nature was considered. No specific assumption on demand was made in this model, and demand did not follow any specific distribution pattern. Only the mean and variance were required to solve the model. The classical optimization technique was applied to the solution methodology. A numerical experiment had been given for validation purposes, and the results were presented. Shortages were allowed in the model and partially backlogged with an exponential backordering function. Various backordering options were offered with increased backordering costs for early delivery. Additionally, 2D and 3D plots were given in the paper to show the model's robustness and application. This model was developed by considering seasonal items such as mobile phones, computers, and apparel. To demonstrate the model's validity, a sensitivity analysis was carried out. This model was for a single item and a single period, which was one limitation of this model. A constant salvage value was considered in this model; additional revenue could be generated with the discounted schemes on leftover items. This methodology can be further extended to cover a multi-period newsvendor problem, multi-item, discounted schemes, non-linear holding cost, and environmental effort-dependent demand or order quantity-dependent demand. The application of blockchain technology is rapidly increasing in SCM. The blockchain and big data can be added to this model for tracing and tracking purposes, as suggested [65–69].

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Conflict of interest

The authors declare that there are no conflicts of interest.

References

1. D. B. Rosenfield, Optimal management of tax-sheltered employee reimbursement programs, *Interfaces*, **16** (1986), 68–72. https://doi.org/10.1287/inte.16.3.68
2. L. Eeckhoudt, C. Gollier, H. Schlesinger, The risk-averse (and prudent) newsboy, *Manage. Sci.*, **41** (1995), 786–794. https://doi.org/10.1287/mnsc.41.5.786
3. K. Chen, T. Xiao, Ordering policy and coordination of a supply chain with two-period demand uncertainty, *Eur. J. Oper. Res.*, **215** (2011), 347–357. https://doi.org/10.1016/j.ejor.2011.06.015
4. O. Jadidi, M. Y. Jaber, S. Zolfaghri, R. Pinto, F. Firouzi, Dynamic pricing and lot sizing for a newsvendor problem with supplier selection, quantity discounts, and limited supply capacity, *Comput. Ind. Eng.*, **154** (2021), 107113. https://doi.org/10.1016/j.cie.2021.107113
5. N. C. Petruzzi, M. Dada, Pricing and the newsvendor problem: A review with extensions, *Oper. Res.*, **47** (1999), 183–194. https://doi.org/10.1287/opre.47.2.183
6. M. Khouja, The single-period (news-vendor) problem: literature review and suggestions for future research, *Omega*, **27** (1999), 537–553. https://doi.org/10.1016/S0305-0483(99)00017-1
7. Y. Qin, R. Wang, A. J. Vakharia, Y. Chen, M. M. Seref, The newsvendor problem: Review and directions for future research, *Eur. J. Oper. Res.*, **213** (2011), 361–374. https://doi.org/10.1016/j.ejor.2010.11.024

8. J. Heydari, B. Momeni, Retailers' coalition and quantity discounts under demand uncertainty, *J. Retailing Consum. Serv.*, **61** (2021), 102557. https://doi.org/10.1016/j.jretconser.2021.102557

9. T. M. Whitin, Inventory control and price theory, *Manage. Sci.*, **2** (1955), 61–68. https://doi.org/10.1287/mnsc.2.1.61

10. E. S. Mills, Uncertainty and price theory, *Q. J. Econ.*, **73** (1959), 116–130. https://doi.org/10.2307/1883828

11. S. Karlin, C. R. Carr, Prices and optimal inventory policy, in *Studies in Applied Probability and Management Science*, **4** (1962), 159–172.

12. F. Y. Chen, H. Yan, L. Yao, A newsvendor pricing game, *IEEE Trans. Syst. Man Cybern. Part A Syst. Humans*, **34** (2004), 450–456. https://doi.org/10.1109/TSMCA.2004.826290

13. B. Afshar-Nadjafi, The influence of sale announcement on the optimal policy of an inventory system with perishable items, *J. Retailing Consum. Serv.*, **31** (2016), 239–245. https://doi.org/10.1016/j.jretconser.2016.04.010

14. S. Kumar, M. Sigroha, K. Kumar, B. Sarkar, Manufacturing/remanufacturing based supply chain management under advertisements and carbon emission process, *RAIRO Oper. Res.*, **56** (2022). https://doi.org/10.1051/ro/2021189

15. B. Sarkar, J. Joo, Y. Kim, H. Park, M. Sarkar, Controlling defective items in a complex multi-phase manufacturing system, *RAIRO Oper. Res.*, **56**(2) (2022), 871–889. https://doi.org/10.1051/ro/2022019

16. S.B. Choi, B.K. Dey, S.J. Kim, B Sarkar, Intelligent servicing strategy for an online-to-offline (O2O) supply chain under demand variability and controllable lead time, *RAIRO Oper. Res.*, **56**(3) (2022), 1623-1653. https://doi.org/10.1051/ro/20220263

17. D. C. Montgomery, M. Bazaraa, A. K. Keswani, Inventory models with a mixture of backorders and lost sales, *Nav. Res. Logist. Q.*, **20** (1973), 255–263. https://doi.org/10.1002/nav.3800200205

18. H. M. Wee, Deteriorating inventory model with quantity discount, pricing and partial backordering, *Int. J. Prod. Econ.*, **59** (1999), 511–518. https://doi.org/10.1016/S0925-5273(98)00113-3

19. E. J. L. Jr, Advanced supply chain planning with mixtures of backorders, lost sales, and lost contract, *Eur. J. Oper. Res.*, **181** (2007), 168–183. https://doi.org/10.1016/j.ejor.2006.06.002

20. C. T. Chang, T. Y. Lo, On the inventory model with continuous and discrete lead time, backorders and lost sales, *Appl. Math. Modell.*, **33** (2009), 2196–2206. https://doi.org/10.1016/j.apm.2008.05.028

21. A. J. Brito, A. T. de Almeida, Modeling a multi-attribute utility newsvendor with partial backlogging, *Eur. J. Oper. Res.*, **220** (2012), 820–830. https://doi.org/10.1016/j.ejor.2012.02.027

22. X. Xu, H. Wang, C. Dang, P. Ji, The loss-averse newsvendor model with backordering, *Int. J. Prod. Econ.*, **188** (2017), 1–10. https://doi.org/10.1080/17510694.2017.1318486

23. Y. Li, J. Ou, Optimal ordering policy for complementary components with partial backordering and emergency replenishment under spectral risk measure, *Eur. J. Oper. Res.*, **284** (2020), 538–549. https://doi.org/10.1016/j.ejor.2020.01.006

24. A. A. Taleizadeh, K. Tafakkori, P. Thaichon, Resilience toward supply disruptions: A stochastic inventory control model with partial backordering under the base stock policy, *J. Retailing Consum. Serv.*, **58** (2021), 102291. https://doi.org/10.1016/j.jretconser.2020.102291
25. R. Maihami, I. Ghalehkhondabi, E. Ahmadi, Pricing and inventory planning for non-instantaneous deteriorating products with greening investment: A case study in beef industry, *J. Clean. Prod.*, **295** (2021), 126368. https://doi.org/10.1016/j.jclepro.2021.126368
26. A. S. Mahapatra, M. S. Mahapatra, B. Sarkar, S. K. Majumder, Benefit of preservation technology with promotion and time-dependent deterioration under fuzzy learning, *Exp. Syst. Appl.*, **201** (2022), 117169. https://doi.org/10.1016/j.eswa.2022.117169
27. M. Tayyab, M.S. Habib, M.S.S. Jajja, B. Sarkar, Economic assessment of a serial production system with random imperfection and shortages: A step towards sustainability, *Comput. Ind. Eng.*, **171** (2022), 108398. https://doi.org/10.1016/j.cie.2022.108398
28. A. Sarkar, R. Guchhait, B. Sarkar, Application of the artificial neural network with multithreading within an inventory model under uncertainty and inflation, *Int. J. Fuzzy Syst.*, **24** (2022), 2318-–2332. https://doi.org/10.1007/s40815-022-01276-1
29. H. Scarf, A min-max solution of an inventory problem, *Studies Math. Theory Inventory Prod.*, 1958.
30. G. Gallego, I. Moon, The distribution free newsboy problem: review and extensions, *J. Oper. Res. Soc.*, **44** (1993), 825–834. https://doi.org/10.1057/jors.1993.141
31. P. L. Abad, Optimal price and order size for a reseller under partial backordering, *Comput. Oper. Res.*, **28** (2001), 53–65. https://doi.org/10.1016/S0305-0548(99)00086-6
32. H. He, S. Wang, Cost-benefit associations in consumer inventory problem with uncertain benefit, *J. Retailing Consum. Serv.*, **51** (2019), 271–284. https://doi.org/10.1016/j.jretconser.2019.06.013
33. Z. Hong, X. Guo, Green product supply chain contracts considering environmental responsibilities, *Omega*, **83** (2019), 155–166. https://doi.org/10.1016/j.omega.2018.02.010
34. C. C. Hsu, K. C. Tan, S. H. M. Zailani, V. Jayaraman, Supply chain drivers that foster the development of green initiatives in an emerging economy, *Int. J. Oper. Prod. Manage.*, **33** (2013), 656-688. https://doi.org/10.1108/IJOPM-10-2011-0401
35. K. Govindan, M. Shaw, A. Majumdar, Social sustainability tensions in multi-tier supply chain: A systematic literature review towards conceptual framework development, *J. Clean. Prod.*, **279** (2020), 123075. https://doi.org/10.1016/j.jclepro.2020.123075
36. H. L. Chan, T. Choi, Y. J. Cai, B. Shen, Environmental taxes in newsvendor supply chains: A mean-downside-risk analysis, *IEEE Trans. Syst. Man Cybern. Syst.*, **50** (2018), 4856–4869. https://doi.org/10.1109/TSMC.2018.2870881
37. X. Shi, H. L. Chan, C. Dong, Value of bargaining contract in a supply chain system with sustainability investment: An incentive analysis, *IEEE Trans. Syst. Man. Cybern. Syst.*, **50** (2018), 1622–1634. https://doi.org/10.1109/TSMC.2018.2880795
38. M. S. Habib, M. Omair, M. B. Ramzan, T. N. Chaudhary, M. Farooq, B. Sarkar, A robust possibilistic flexible programming approach toward a resilient and cost-efficient biodiesel supply chain network, *J. Clean. Prod.*, **366** (2022), 132752. https://doi.org/10.1016/j.jclepro.2022.132752

39. B. Shen, T. M. Choi, H. L. Chan, Selling green first or not? a bayesian analysis with service levels and environmental impact considerations in the big data era, *Technol. Forecast. Soc. Change*, **144** (2019), 412–420. https://doi.org/10.1016/j.techfore.2017.09.003

40. D. Yadav, R. Singh, A. Kumar, B. Sarkar, Reduction of pollution through sustainable and flexible production by controlling by-products, *J. Environ. Inf.*, **40** (2022), 106–124.

41. B. Q. Tan, F. Wang, J. Liu, K. Kang, F. Costa, A blockchain-based framework for green logistics in supply chains, *Sustainability*, **12** (2020), 4656. https://doi.org/10.3390/su12114656

42. A. Kumar, R. Liu, Z. Shan, Is blockchain a silver bullet for supply chain management? technical challenges and research opportunities, *Decis. Sci.*, **51** (2020), 8–37. https://doi.org/10.1111/deci.12396

43. P. Liu, Y. Long, H. C. Song, Y. D. He, Investment decision and coordination of green agri-food supply chain considering information service based on blockchain and big data, *J. Clean. Prod.*, **277** (2020), 123646. https://doi.org/10.1016/j.jclepro.2020.123646

44. B. Sarkar, B. Ganguly, S. Pareek, L.E. Cárdenas-Barrón, A three-echelon green supply chain management for biodegradable products with three transportation modes, *Comput. Ind. Eng.*, **174** (2022), 108727. https://doi.org/10.1016/j.cie.2022.108727

45. S. S. Sana, Price competition between green and non green products under corporate social responsible firm, *J. Retailing Consum. Serv.*, **55** (2020), 102118. https://doi.org/10.1016/j.jretconser.2020.102118

46. A. S. H. Kugele, W. Ahmed, B. Sarkar, Geometric programming solution of second degree difficulty for carbon ejection controlled reliable smart production system, *RAIRO Oper. Res.*, **56** (2022), 1013–1029. https://doi.org/10.1051/ro/2022028

47. B. Sarkar, S. Kar, K Basu, R. Guchhait, A sustainable managerial decision-making problem for a substitutable product in a dual-channel under carbon tax policy, *Comput. Ind. Eng.*, **172**(B) (2022), 108635. https://doi.org/10.1016/j.cie.2022.108635

48. I. Moon, W.Y. Yun, B. Sarkar, Effects of variable setup cost, reliability, and production costs under controlled carbon emissions in a reliable production system, *Euro. J. Indust. Eng.*, **16**(4) (2022), 371–397. https://doi.org/10.1504/EJIE.2022.123748

49. P. Abad, Determining optimal price and order size for a price setting newsvendor under cycle service level, *Int. J. Prod. Econ.*, **158** (2014), 106–113. https://doi.org/10.1016/j.ijpe.2014.07.008

50. S. Alaei, M. Setak, Multi objective coordination of a supply chain with routing and service level consideration, *Int. J. Prod. Econ.*, **167** (2015), 271–281. https://doi.org/10.1016/j.ijpe.2015.06.002

51. B. Pal, S. S. Sana, K. Chaudhuri, A distribution-free newsvendor problem with nonlinear holding cost, *Int. J. Syst. Sci.*, **46** (2015), 1269–1277. https://doi.org/10.1080/00207721.2013.815828

52. M. A. Abdel-Aal, M. N. Syed, S. Z. Selim, Multi-product selective newsvendor problem with service level constraints and market selection flexibility, *Int. J. Prod. Econ.*, **55** (2017), 96–117. https://doi.org/10.1080/00207543.2016.1195932

53. X. A. Chen, Z. Wang, H. Yuan, Optimal pricing for selling to a static multi-period newsvendor, *Oper. Res. Lett.*, **45** (2017), 415–420. https://doi.org/10.1016/j.orl.2017.05.006

54. X. Hu, P. Su, The newsvendor's joint procurement and pricing problem under price-sensitive stochastic demand and purchase price uncertainty, *Omega*, **79** (2018), 81–90. https://doi.org/10.1016/j.omega.2017.08.002

55. S. V. S. Padiyar, V. Vandana, N. Bhagat, S. R. Singh, B. Sarkar, Joint replenishment strategy for deteriorating multi-item through multi-echelon supply chain model with imperfect production under imprecise and inflationary environment, *RAIRO Oper. Res.*, **56** (2022), 3071–3096. https://doi.org/10.1051/ro/2022071

56. B. Sarkar, D. Takeyeva, R. Guchhait, M. Sarkar, Optimized radio-frequency identification system for different warehouse shapes, *Know. Based Syst.*, **258** (2022), 109811. https://doi.org/10.1016/j.knosys.2022.109811

57. J. Shi, Q. Du, F. Lin, Y. Li, L. Bai, R. Y. Fung, et al., Coordinating the supply chain finance system with buyback contract: A capital-constrained newsvendor problem, *Comput. Ind. Eng.*, **146** (2020), 106587. https://doi.org/10.1016/j.cie.2020.106587

58. A. Govindarajan, A. Sinha, J. Uichanco, Distribution-free inventory risk pooling in a multilocation newsvendor, *Manage. Sci.*, **67** (2020), 2272-2291. https://doi.org/10.1287/mnsc.2020.3719

59. Y. Fan, Y. Feng, Y. Shou, A risk-averse and buyer-led supply chain under option contract: Cvar minimization and channel coordination, *Int. J. Prod. Econ.*, **219** (2020), 66–81. https://doi.org/10.1016/j.ijpe.2019.05.021

60. M. Sarkar, B. Sarkar, A. Dolgui, An automated smart production with system reliability under a leader-follower strategy of supply chain management, In: Kim, D.Y., von Cieminski, G., Romero, D. (eds) Advances in Production Management Systems. Smart Manufacturing and Logistics Systems: Turning Ideas into Action. APMS 2022. *IFIP International Conference on Advances in Production Management Systems*, **663** (2022), 459–467, Springer, Cham. https://doi.org/10.1007/978 − 3 − 031 − 16407 − 1_54

61. C. Bi, B. Zhang, F. Yang, Y. Wang, G. Bi, Selling to the newsvendor through debt-shared bank financing, *Eur. J. Oper. Res.*, **296** (2021), 116-130. https://doi.org/10.1016/j.ejor.2021.02.025

62. V. Hovelaque, J. L. Viviani, M. A. Mansour, Trade and bank credit in a non-cooperative chain with a price-sensitive demand, *Int. J. Prod. Res.*, **60** (2021), 1553-1568. https://doi.org/10.1080/00207543.2020.1866222

63. M. Ullah, I. Khan, B. Sarkar, Dynamic pricing in a multi-period newsvendor under stochastic price-dependent demand, *Mathematics*, **7** (2019), 520. https://doi.org/10.3390/math7060520

64. H. Lee, E. J. L. Jr, Modeling customer impatience in a newsboy problem with time-sensitive shortages, *Eur. J. Oper. Res.*, **205** (2010), 595–603. https://doi.org/10.1016/j.ejor.2010.01.028

65. P. Centobelli, R. Cerchione, E. Esposito, E. Oropallo, Surfing blockchain wave, or drowning? shaping the future of distributed ledgers and decentralized technologies, *Technol. Forecast. Soc. Change*, **165** (2021), 120463. https://doi.org/10.1016/j.techfore.2020.120463

66. P. Centobelli, R. Cerchione, E. Oropallo, W. H. El-Garaihy, T. Farag, K. H. A. Shehri, Towards a sustainable development assessment framework to bridge supply chain practices and technologies, *Sustainable Dev.*, **30** (2020), 647–663. https://doi.org/10.1002/sd.2262

67. M. K. Lim, Y. Li, C. Wang, M. L. Tseng, A literature review of blockchain technology applications in supply chains: A comprehensive analysis of themes, methodologies and industries, *Comput. Ind. Eng.*, **154** (2021), 107133. https://doi.org/10.1016/j.cie.2021.107133

68. X. Liu, A. V. Barenji, Z. Li, B. Montreuil, G. Q. Huang, Blockchain-based smart tracking and tracing platform for drug supply chain, *Comput. Ind. Eng.*, **161** (2021), 107669. https://doi.org/10.1016/j.cie.2021.107669

69. Z. Liu, Z. Li, A blockchain-based framework of cross-border e-commerce supply chain, *Int. J. Inf. Manage.*, **52** (2020), 102059. https://doi.org/10.1016/j.ijinfomgt.2019.102059