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# NEWSVENDOR SYSTEM NEGLECT REVISITED USING AN ENHANCED NORMATIVE METHOD

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Abstract. *The purpose of this study is to propose an enhanced normative method to explain the system neglect effect and to generate an appropriate reaction to satisfy consumers' uncertain demand. Given that the normative method (single exponential smoothing method, or SESM) does not consider that system neglect affects newsvendor decision making and minimization of inventory costs, it cannot provide the optimal order decision. Therefore, the present study utilizes the optimal detection rule (ODR) to revise the previous normative method. In this proposed method, the decision-making difference between ODR and SESM in a newsvendor system neglect setting is first analyzed, and then system neglect effects from newsvendor decision making are expressly revisited. The research findings indicate: (i) the system neglect effect contains an appropriate deviation under specific conditions (underselling a high-profit product at an increasing stage and underselling a low-profit product at a decreasing stage) and (ii) under specific conditions, the system neglect effect could be utilized to reduce inventory costs and satisfy uncertain demand from end customers. Finally, the research and managerial implications and suggestions are summarized and discussed.*

**Keywords:** Inventory cost, Uncertain demand, System neglect, Single exponential smoothing method, Optimal detection rule

1. **Introduction.** The business environment is becoming increasingly volatile. Intense business promotions and competitive activities result in uncertain increases in demand [1]. In practice, demand information is usually insufficient in exactly forecasting changes in demand [2-4]. Reacting appropriately to information about the end consumer of products and services provides a critical way to construct a competitive advantage. Businesses are continually adopting technological and managerial methods to improve the reaction efficiency in their operational processes to satisfy consumers [5,6]. The newsvendor model is extensively utilized to improve operational processes to address uncertain demand from end consumers. In today's business environment, many companies apply software to managing inventory replenishment decisions and order quantities for seasonal/fashion items (so-called newsvendor decisions). Surprisingly, employees, and not automated systems, make the decisions. For example, many investigations have shown that even when an automated inventory replenishment system is implemented in a retail store, a store manager may sometimes choose to bypass the system and, instead, manually decide on orders.

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The store manager could suffer from the influence of human behavior when engaging in irrational inventory planning [7,8].

Therefore, measuring inventory ordering decisions of decision makers has received significant attention from the area of behavioral operations management [9-16]. Previous studies indicated that decision makers make decisions that systematically deviate from those suggested by normative models. Thus, among a variety of individual behaviors, system neglect results from behavior of the decision makers and is established using the single exponential smoothing method (SESM), which is viewed as the normative method. However, one problem with SESM is that it does not consider how system neglect affects newsvendor decision making and the benefits resulting from system neglect [13,17]. Meanwhile, the traditional normative method does not consider minimization of inventory costs, which cannot result in optimal order decisions. Thus, essential issues are whether deviations from the system neglect effect are appropriate and how the influence of human behavior in newsvendor decisions is measured.

Regarding saving inventory costs, the demand change detection method called the optimal detection rule (ODR) proposed by Juan and Wang [18] can remedy the drawbacks of SESM, which ignores the system neglect effects in detecting changes in demand. What is the result if the traditional normative method is not the best choice for a newsvendor-type decision maker? With SESM, newsvendor highs and lows in the data offset each other when taken as an average. With ODR, orders change when demand observations exceed a critical threshold. Therefore, this study utilizes ODR to revise the previous normative method.

Against this background, an enhanced normative method is proposed in this study to remedy the gaps in the previous literature. The proposed method emphasizes offering not only forecasting approaches but also containing the newsvendor system neglect effect to generate an appropriate reaction to satisfy end consumers' uncertain demand. We first analyze the decision-making difference between ODR and SESM in the newsvendor system neglect setting and then expressly revisit the effect of system neglect on newsvendor decision making. The enhanced normative method is utilized to respond to the following research questions.

1) Is system neglect still irrational when we use ODR as the enhanced normative model?
2) How should the manager recognize system neglect?
3) What is the benefit of revisiting system neglect?

In this study, computational experiments are conducted to observe the difference between the decisions generated by SESM and ODR. Strategies for responding to newsvendor system neglect are developed to improve the performance of newsvendor-type decision makers influenced by system neglect: exaggerate the probability of change in relatively stable environments and underestimate the probability in relatively unstable environments. Moreover, we attempt to verify that system neglect is not completely irrational and that the influence of system neglect may help a decision maker perform better than software.

The remainder of this paper is organized as follows. The following section presents the problem description. The latest detection method, ODR, is then introduced. Finally, a comparison between ODR and SESM is illustrated, and the newsvendor system neglect effect is explained using the enhanced normative method. The paper concludes with a summary of the main findings, implications, and suggestions for future research.

## 2. **Problem Description.**

A newsvendor offers products to end customers in a series of periods. Before the beginning of each period, the newsvendor needs to predict uncertain and random demand shifts and determine the number of units of products to be ordered.

Leftover products have zero value. When surplus products exist, the newsvendor needs to afford excess costs. Shortage costs exist if unfulfilled demand occurs. Let $d_t$ denote the demand in period $t$. The demand process is as follows.

$$d_t = \mu_t + \varepsilon_t \tag{1}$$

$$\mu_t = \begin{cases} \mu_g + v_t(\mu_h - \mu_g), & \text{if } \mu_{t-1} = \mu_g \\ \mu_h, & \text{else} \end{cases} \tag{2}$$

where $\varepsilon_t \sim N(0, \sigma^2)$ and $v_t \sim B(1, p)$ are independent random variables. For convenience, the descriptions of the symbols are explained in Table 1.

TABLE 1. Notations

| Symbol | Description |
|---|---|
| $c_e$ | Excess cost per unit (= cost per unit – salvage value per unit) |
| $c_s$ | Shortage cost per unit (= revenue per unit – cost per unit) |
| $\mu_g$ | Expected value of distribution $g$ |
| $\mu_h$ | Expected value of distribution $h$ |
| $\sigma$ | Standard deviation of the demand distribution |
| $p$ | Transition probability that the demand distribution changes in a period |
| $F_{t-1}$ | Forecast in period $t$ under the exponential smoothing method |
| $\alpha$ | Smoothing constant of the exponential smoothing method |
| $k$ | Threshold value that determines whether demand changes |

Assume that prior demand is already observed. The newsvendor needs to decide whether the observed demand data provide a reason to modify a previous forecast for the next period. If the newsvendor believes that demand has not changed, the newsvendor views the variation in demand histories as noise and sticks to the previous order quantity. If a change occurs in the demand level, the newsvendor modifies the order quantity instead. Briefly, the newsvendor's task is to differentiate step changes from noise. By adopting the SESM as the normative forecasting method, Kremer et al. [13] used a laboratory experiment to study the newsvendor's behavior under the previously described task. In Kremer et al. [13], the optimal forecasts can be formalized by the following equations.

$$F_t = F_{t-1} + \alpha^*(x_{t-1} - F_{t-1}) \tag{3}$$

$$\alpha^* = \frac{2}{1 + \sqrt{1 + 4\sigma^2/W}} \tag{4}$$

$$W = \frac{(\mu_g - \mu_f)^2}{\sigma^2} \cdot p(1-p) \tag{5}$$

In an experimental study, Kremer et al. [13] utilized SESM as the normative method to establish irrational behavior system neglect. The system neglect presented relatively greater overreaction for low values of $\alpha$ and greater underreaction for high values of $\alpha$. Obviously, if $\mu_g < \mu_h$, individuals under the influence of system neglect order more than that suggested by SESM when $p$ is very small; if $\mu_g > \mu_h$, they order more instead.

3. **Substitute Benchmark: Optimal Detection Rule.** When demand may change as described by Equations (1) and (2), the following strategy can assess the demand change through a lower inventory cost than from SESM [18].

**Detection rule.** When $0 < \mu_g < \mu_h$, if $x_{t-1} > k \cdot \frac{\mu_g + \mu_h}{2}$, then the demand level in period $t$ is believed to be $\mu_h$; otherwise, the demand level in period $t$ is believed to be $\mu_g$.

When $0 < \mu_h < \mu_g$, if $x_{t-1} > k \cdot \frac{\mu_g + \mu_h}{2}$, then the demand level in period $t$ is believed to be $\mu_g$; otherwise, the demand level in period $t$ is believed to be $\mu_h$.

Parameter $k$ is a real number, namely, the detection threshold. The detection rule provides an important observation: differentiating a step change from random noise is equal to establishing a suitable threshold of prior demand $x_{t-1}$. With a low value of $k$, the possibility of a change in demand should be discarded, whereas with a high value of $k$, the possibility should have a dramatic influence on order quantity adjustments. The optimal detection threshold can be calculated as follows [18].

$$k^* = \begin{cases} 1 + \dfrac{2\sigma^2}{\mu_h^2 - \mu_g^2} \ln \dfrac{-(1-p)p + (1-p)^2 R}{p}, & p < \dfrac{R}{R+1} \\ -\infty, & \text{else if } \mu_g < \mu_h \\ +\infty, & \text{else if } \mu_g > \mu_h \end{cases} \tag{6}$$

where

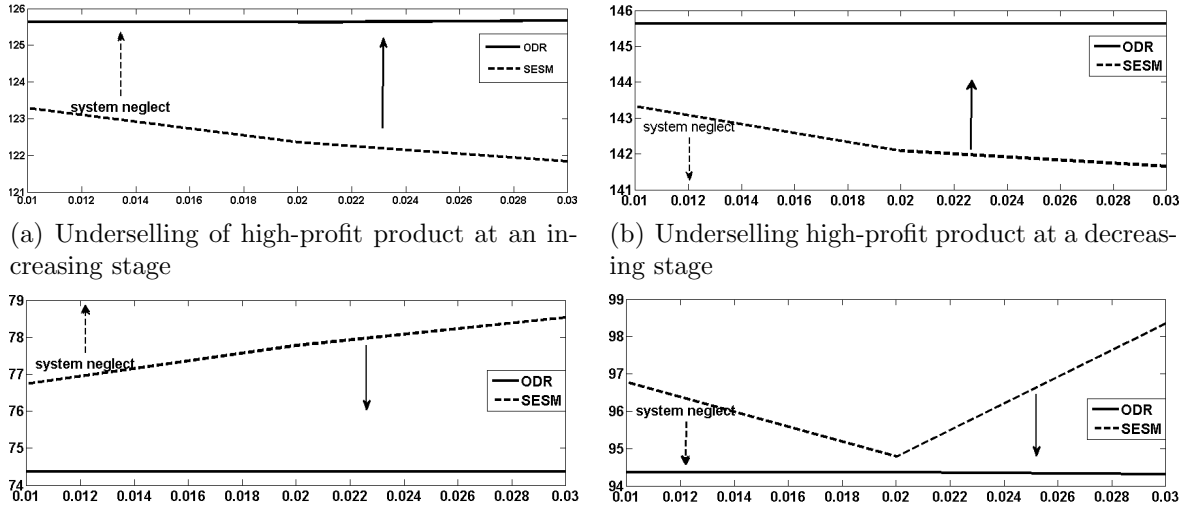
$$R = \frac{-c_s(\mu_h - \mu_g) + (c_e + c_s) \int_{q_g}^{q_h} G(x)dx}{c_s(\mu_h - \mu_g) - (c_e + c_s) \int_{q_g}^{q_h} H(x)dx} \tag{7}$$

$G(x)$ and $H(x)$ represent the distribution functions $N(\mu_g, \sigma^2)$ and $N(\mu_h, \sigma^2)$, respectively. Obviously, the optimal detection threshold depends jointly on the demand distribution, transitional probability, and cost structure parameters. When detecting a step change in the demand process formulated by Equations (1) and (2), the inventory costs associated with ODR might be lower than those with SESM [18]. From the point of view of this study, the possibility of saving inventory costs justifies replacing SESM with ODR as the benchmark.

4. **ODR versus SESM.** In this section, we compare the order decisions under ODR and SESM using numerical experiments and investigate the influence of applying ODR as the normative approach in recognition of system neglect relative to applying SESM. Based on the massive experiments under different parameter settings, we select four representative settings to illustrate the research findings.

Set $\sigma = 20$. Define $q_g = G^{-1}\left(\frac{c_s}{c_e + c_s}\right)$ and $q_h = H^{-1}\left(\frac{c_s}{c_e + c_s}\right)$. To clarify whether system neglect is completely irrational, we compare the order decisions under ODR and the single exponential smoothing method in four different experimental settings. In the first, $c_e = 1$, $c_s = 9$, $\mu_g = 100$, $\mu_h = 120$, $p \in \{0.01, 0.02, 0.03\}$, and $F_t = q_g$; in the second, $c_e = 1$, $c_s = 9$, $\mu_g = 120$, $\mu_h = 100$, $p \in \{0.01, 0.02, 0.03\}$, and $F_t = q_g$; in the third, $c_e = 9$, $c_s = 1$, $\mu_g = 100$, $\mu_h = 120$, $p \in \{0.01, 0.02, 0.03\}$, and $F_t = q_g$; and in the fourth, $c_e = 9$, $c_s = 1$, $\mu_g = 120$, $\mu_h = 100$, $p \in \{0.01, 0.02, 0.03\}$, and $F_t = q_g$. In the four settings, the values of $q_g$ and $q_h$ are as follows: (a) $q_g = 125.6310$, $q_h = 145.6310$; (b) $q_g = 145.6310$, $q_h = 125.6310$; (c) $q_g = 74.3690$, $q_h = 94.3690$; and (d) $q_g = 94.3690$, $q_h = 74.3690$. The experimental results are shown in Figure 1.

Figure 1 illustrates a comparison between the average order decision under ODR and that under SESM. The average order decision under ODR is the average of 1,000 repeated order decisions in the four different experimental settings. Similarly, the average decision under SESM is obtained. Figures 1(a) and 1(d) illustrate that, when facing the risk of upward (downward) demand change and $c_e < c_s$ ($c_e > c_s$), the average order quantity under ODR is closer to the optimal order quantity after a change in demand. This finding indicates that the situation of newsvendors using ODR presents a relatively greater overreaction for low values of $p$ than for those using SESM. Similarly, when faced with the risk of decreasing (increasing) demand and $c_e < c_s$ ($c_e > c_s$), Figures 1(b) and 1(c) indicate that newsvendors using ODR show relatively greater underreaction for low values




(a) Underselling of high-profit product at an increasing stage

(b) Underselling high-profit product at a decreasing stage

(c) Underselling low-profit product at an increasing stage

(d) Underselling low-profit product at a decreasing stage

Note: (a) $c_e = 1$, $c_s = 9$, $\mu_g = 100$, $\mu_h = 120$; (b) $c_e = 1$, $c_s = 9$, $\mu_g = 120$, $\mu_h = 100$; (c) $c_e = 9$, $c_s = 1$, $\mu_g = 100$, $\mu_h = 120$; (d) $c_e = 9$, $c_s = 1$, $\mu_g = 120$, $\mu_h = 100$.

FIGURE 1. Comparison of ODR and SESM in order decisions

of $p$ than those using SESM. Thus, we conclude that system neglect relatively weakens when ODR is used as the benchmark in situations 1(a) and 1(d) and becomes relatively stronger in situations 1(b) and 1(c).

The findings help us understand the influence of system neglect on newsvendors' order behavior. Because the expected inventory costs under ODR are lower than those under SESM, the economic behavior in the order quantity decision suggests the use of ODR rather than SESM. Recall that newsvendors who are influenced by the system neglect effect exaggerate the transitional probability when this probability is very low. Thus, when the transitional probability is very low, newsvendors under the system neglect effect order more (less) than the order quantity suggested by SESM when facing a possible upward (downward) demand shock.

5. **Summary of Newsvendor Performance.** To facilitate the understanding, Figures 1(a) and 1(d) illustrate a slight deviation in the order decision from SESM to reduce the gap between the order decision under SESM and ODR. Thus, Figures 1(a) and 1(d) are set as the moderate system neglect that is appreciated for reducing inventory costs. Table 2 also indicates that newsvendors in conditions 1(a) and 1(d) slightly influenced by system neglect outperform rational newsvendors when using the previous SESM to forecast demand. Moreover, from the perspective of improving customer service, two situations are explained: (1) newsvendors influenced by system neglect can outperform rational decisions when $c_e < c_s$ and product demand increases at a low probability, and (2) newsvendors influenced by system neglect can outperform rational newsvendors when $c_e > c_s$ and product demand decreases at a low probability.

The observations offer managerial insights into human resource management. As an example, take products for which $c_e < c_s$. In this situation, the purchasing cost is less than half the retail price. Thus, $c_e < c_s$ is identified as indicating high-profit products. From Table 2, we infer that when purchasing high-profit products in a market in which demand may increase at a low probability, a manager influenced by system neglect is more appreciated than a rational manager. Furthermore, when demand is expected to increase

TABLE 2. Can managers benefit from system neglect?

| Conditions | **Upward demand change** | **Downward demand change** |
|---|---|---|
| $c_e < c_s$ | **Yes**[(a)] | No[(b)] |
| | **Improving customer service** | Decreasing customer service |
| $c_e > c_s$ | No[(c)] | **Yes**[(d)] |
| | Improving customer service | **Decreasing customer service** |

at a low probability, less staff training on managing system neglect is worth praising. The same suggestions are also appropriate for products with $c_e > c_s$ when their demand decreases at a low probability.

In practice, many companies always modify the forecasts generated by the software using SESM or manually develop forecasts. Kremer et al. [13] mentioned that a systematic deviation in order quantity occurred from decisions generated by SESM. The deviation is established as irrational, and, thus, believed to be harmful to the performance of inventory systems. In this study, Figure 1 illustrates the situation in which transitional probability $p$ is close to 0; if $c_e < c_s$ and $\mu_g < \mu_h$, then slightly overreacting to $p$ can reduce the gap between actual order decisions and decisions suggested by ODR. Hence, in such cases, the forecasters influenced by system neglect may outperform the rational forecasters that adopt SESM. If $c_e > c_s$ and $\mu_g > \mu_h$, system neglect is also positive for reducing inventory costs. Otherwise, system neglect increases inventory costs.

6. **Conclusions and Suggestions.** The SESM was used in previous studies to determine the system neglect effect in the newsvendor decision process [13]. However, how system neglect affects newsvendor decision making and the benefits brought by system neglect and how to consider the minimization of inventory costs received significant attention. Thereby, to fill the research gaps, an enhanced normative method is proposed in this paper. The ODR, a revision of the SESM (traditional normative method), brings lower inventory costs for newsvendors. The research findings of this study explain the concept that deviation from SESM may be beneficial to improving the performance of inventory systems.

According to the research findings, in the traditional normative method (SESM), the system neglect effect was found to reflect not completely rational behavior. The deviation generated by SESM causes necessarily decreasing newsvendor decision performance, and the conclusion is reached that deviations are irrational. To improve the performance of the newsvendor's decision, the proposed enhanced normative method is utilized to validate the concept that an appropriate deviation from SESM can generate decisions that decrease the inventory costs of newsvendors, with two positive effect conditions including: (1) high-profit product ($c_e < c_s$) with a demand increase ($\mu_g < \mu_h$), and (2) low-profit product ($c_e > c_s$) with a demand decrease ($\mu_g > \mu_h$). Therefore, we emphasize using the traditional normative method (SESM) that a conscious deviation exists, and the strategy for decreasing inventory costs causes a deviation of the SESM.

Meanwhile, the statements of this study have significant implications: when managers offer a high-profit product that is undersold at an increasing stage ($c_e < c_s$, $\mu_g < \mu_h$) or a low-profit product that is undersold at a decreasing stage ($c_e > c_s$, $\mu_g > \mu_h$), if the managers cannot obtain enough information on inventory costs, the system neglect effect of managers then decreases. In addition, when managers offer a high-profit product that is undersold at a decreasing stage ($c_e < c_s$, $\mu_g > \mu_h$) or a low-profit product that

is undersold at an increasing stage ($c_e > c_s$, $\mu_g < \mu_h$), if the managers cannot efficiently deliver inventory cost information to managers, the system neglect effect is enhanced.

From the perspective of decreasing inventory costs, when managers offer a high-profit product that is undersold at an increasing stage ($c_e < c_s$, $\mu_g < \mu_h$) or a low-profit product that is undersold at a decreasing stage ($c_e > c_s$, $\mu_g > \mu_h$), they could benefit from the appropriate system neglect effect (costs decrease). Additionally, when managers offer a high-profit product that is undersold at a decreasing stage ($c_e < c_s$, $\mu_g > \mu_h$) or a low-profit product that is undersold at an increasing stage ($c_e > c_s$, $\mu_g < \mu_h$), they could suffer damage (costs increase) from the system neglect effect. The conclusion implies that information transparency of inventory costs should be improved when managers offer a high-profit product that is undersold at an increasing stage. Meanwhile, information transparency of inventory costs should be decreased when a high-profit product is undersold at a decreasing stage. In contrast, information transparency of inventory costs should be decreased when a low-profit product is undersold at an increasing stage, and information transparency of inventory costs should be improved when managers offer a low-profit product that is undersold at an increasing stage. From the perspective of improving customer service, newsvendors who undersell at an increasing stage and are affected by the system neglect effect offer high performance to satisfy customer needs. Conversely, newsvendors who undersell at a decreasing stage offer lower performance than before.

The potential variables of the inventory cost and external market could be concerns in future studies because they are highly sensitive to system neglect regarding the newsvendor issue. Meanwhile, future studies could use the approach adopted in this study to address the cold chain logistics issue. Cold chain logistics are required to achieve higher service levels and higher economics inventory costs and, simultaneously, must respond to a rigorous challenge of shorter and more uncertain market demand. These issues also serve to validate the practicability of the enhanced normative method proposed in this study.

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