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## Extending CVP Analysis Under Demand Functions and Congestion Costs

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# Extending CVP Analysis Under Demand Functions and Congestion Costs


## ABSTRACT

This study develops an extended cost–volume–profit (CVP) model that integrates demand functions and congestion costs within a unified analytical framework. Traditional CVP analysis assumes constant selling prices and linear cost behavior and is, primarily for short-term profit planning. Previous studies have introduced demand functions to relax the constant-price assumption, reformulating CVP analysis as a profit-maximization model. By contrast, research on congestion costs has mainly examined cost-side effects of increased utilization, while demand adjustments through pricing or customer balking and reneging behavior have received limited attention. Building on Hirai and Kataoka (2024), this study explicitly incorporates demand elasticity and congestion costs into CVP analysis. Simulation results demonstrate how these factors jointly affect optimal pricing, sales volume, and capacity utilization. This highlights the strategic role of CVP analysis in proactive pricing decisions.



**Keywords:** CVP analysis, demand function, congestion costs, balking/reneging behavior, pricing

# 1 INTRODUCTION

Many standard management accounting and cost accounting textbooks explain cost–volume–profit (CVP) analysis as a technique useful for short-term profit planning (Horngren, Datar, & Rajan, 2015). CVP analysis estimates expected profits, calculates the sales revenue or volume required to achieve a target profit, and evaluates the effects of profit-improvement measures or changes in break-even sales.

CVP analysis typically introduces several simplifying assumptions: (i) production and sales volume, or revenue, is the sole variable representing the level of activity; (ii) costs can be clearly classified into variable and fixed costs within the relevant range, allowing for a linear cost function; (iii) selling price, unit variable cost, and total fixed costs remain constant regardless of the production or sales level; and (iv) production volume equals sales volume (Dickey, 1960, pp. 18–19; Horngren, Datar, & Rajan, 2015, pp. 94–95). This study refers to the CVP analysis model based on these assumptions as traditional CVP analysis.

A substantial body of research has extended the traditional CVP analysis model. A notable stream of research originates with Dean (1951) (Dean, 1951; Constantinides et al., 1981; Lau & Lau, 1987; Yunker, 2001). Dean (1951) criticized traditional CVP analysis for assuming a constant selling price regardless of sales volume. He emphasized the importance of decision-making that incorporates demand curves and marginal concepts. As this research developed optimization models based on nonlinear revenue functions, traditional CVP analysis evolved from a simplified tool for short-term profit planning into a decision-making model focused on profit maximization through marginal analysis, specifically determining the optimal sales volume. Constantinides et al. (1981) incorporated a linear demand function into stochastic CVP analysis to model the relationship between price and sales volume. Lau and Lau (1987) linked the demand function to pricing decisions, establishing a theoretical foundation for a model that treats price and production quantity as decision variables.

Recent research findings on *congestion costs* have enhanced understanding of cost behavior with respect to capacity utilization. The cost of congestion refers to "the additional costs incurred as a result of congestion" (Hirai & Kataoka, 2024). For instance, Banker et al. (1988) explained congestion costs using queueing theory, and Balakrishnan and Soderstrom (2000) empirically examined congestion costs in obstetrics and gynecology departments. However, these studies did not focus on customer balking or reneging behavior under congested conditions (Hirai & Kataoka, 2024; Kataoka et al., 2025). Recent surveys indicate that waiting time is the primary reason retailers lose customers (Yu, 2020).

In response, Hirai and Kataoka (2024) estimated a new profit function that incorporates capacity utilization and congestion costs based on queueing theory. They derived the optimal

sales volume and optimal utilization rate. However, their analysis assumes a constant price and does not incorporate the relationship between selling price and demand, which is necessary to control utilization effectively. Thus, the perspective of optimizing demand—and consequently, utilization—through pricing decisions in the presence of congestion costs remains unexplored.

Accordingly, this study relaxes the assumptions of the traditional CVP analysis model and proposes a new CVP analysis framework that incorporates both a demand function and congestion costs. We extend Hirai and Kataoka's (2024) model to examine the effects of demand functions and congestion costs on CVP analysis through simulation.

The remainder of this paper is organized as follows. Section 2 reviews previous studies and clarifies the significance of incorporating demand functions and congestion costs into CVP analysis. Section 3 extends Hirai and Kataoka's (2024) model by presenting a new CVP analysis that integrates demand functions and congestion costs, conducts simulations of the proposed model, and summarizes the key findings. Sections 4 and 5 discuss the implications of the simulation results and provide a summary and concluding remarks, respectively.

## 2 PREVIOUS STUDIES

### 2.1 From Traditional CVP Analysis to CVP Analysis as an Optimization Model

According to Solomons (1968, p. 35), Hess (1903) was the first to refer to the fundamental concept of CVP analysis as a profit-planning model by distinguishing variable costs from fixed costs. This distinction ultimately focuses on the variability of costs in response to changes in output. Subsequently, Knoeppel (1931) systematized the core structure of CVP analysis and emphasized the importance of incorporating profit planning—defined as the process of examining strategies to achieve the required profit for the following period—into budgetary control. Proposed as a technique to support profit planning, the traditional CVP analysis model is now explained in most management accounting textbooks and is regarded as one of the most popular techniques in that field.

However, the traditional model relies on simplifying assumptions: (i) production and sales volume, or sales revenue, serve as the sole measures of activity or drivers; (ii) costs can be clearly classified into variable and fixed components within the relevant range, allowing the estimation of a linear cost function; (iii) the selling price per unit, variable cost per unit, and total fixed costs remain constant regardless of production or sales levels; and (iv) production volume equals sales volume (Dickey, 1960, pp. 18–19; Horngren et al., 2015, pp. 94–95). Thus, the model emphasizes managerial convenience, an orientation that has persisted in contemporary textbooks.

Regarding these assumptions of the traditional CVP analysis model, Dean's (1951) pioneering study highlighted the limitations of linear break-even analysis. It emphasized the importance of decision-making that considers demand curves and marginal concepts. Specifically, methods for increasing profit expanded beyond simple cost reduction or increases in sales volume. A theoretical framework was presented in which managers seek optimal volume and price levels by considering the relationship between sales volume and selling price (i.e., the demand function). Consequently, CVP analysis evolved into a decision-making model enabling managers to manage profit through pricing decisions.

Subsequently, Constantinides et al. (1981) incorporated a linear demand function into stochastic CVP analysis by modeling the causal relationship between price and sales volume. Furthermore, Lau and Lau (1987) mathematically analyzed how demand (sales volume) responds when a firm treats selling price as a decision variable and how this response affects the overall profit structure. Rather than merely conducting break-even analysis, CVP analysis began to incorporate strategic considerations, such as profit maximization and achieving target profits through price control, while accounting for the price elasticity of demand. Lau and Lau (1987) assumed a more realistic, complex demand curve in which the price elasticity of demand is not constant. They proposed an algorithm for deriving an optimal solution that simultaneously satisfies two conditions: adjusting demand through pricing and determining production quantity in light of inventory and production capacity. In other words, Lau and Lau (1987) established selling price as a variable that managers strategically control. Although their primary focus was developing CVP analysis under uncertainty, their major contribution lay in treating the demand function not as an exogenous assumption but as a structure linked to pricing decisions. Building on prior research, Yunker (2001) developed a model incorporating an "economic demand function" into stochastic CVP. Yunker (2001) treats price neither as a constant nor as a random variable, but as a fundamental decision variable for managers.

Despite a series of studies on CVP analysis, beginning with Dean (1951), which addressed the incorporation of demand functions and constraints, little consideration has been given to the impact of waiting lines and congestion costs that arise in production and service delivery processes on the profit function.

### 2.2 Congestion Costs and the Hirai and Kataoka (2024) Model

In recent years, several studies have investigated **congestion costs** to understand cost behavior in relation to capacity utilization. These studies suggest that as unused capacity is fully utilized and the utilization rate approaches 100 percent, congestion costs arise (Banker et al., 1988; Hirai & Kataoka, 2024; Kataoka et al., 2025). For instance, Banker et al. (2014) argue

that greater demand uncertainty leads firms to adopt a higher proportion of fixed costs to avoid increasing congestion costs. They demonstrate that firms increase their capacity in advance and choose a cost structure with relatively high fixed costs to mitigate the congestion costs expected as utilization approaches 100 percent.

Building on previous studies, Hirai and Kataoka (2024) model congestion costs using queueing theory and incorporate them into cost behavior to develop a new profit function and simulation model.

A critical aspect of congestion costs is the opportunity losses and foregone profits from customers' balking or reneging in response to non-monetary (i.e., invisible or hidden) costs. Hirai and Kataoka (2024) examine customer behaviors such as **balking**, in which customers choose not to join a queue after observing its length, and **reneging**, in which customers leave the queue after initially joining. They estimate the total number of customers who are considering purchasing or consuming the firm's products or services, as well as the number who engage in balking or reneging.

Consequently, let the demand rate for the product per unit time (i.e., sales volume) be λ, the processing rate per unit time (i.e., processable volume or capacity) be μ, and the proportion of customers who engage in balking or reneging relative to the total number of customers be $n$ ($0 \leq n \leq 1$). The number of customers who engage in balking or reneging can be expressed as

$$\frac{(CT - T_e) \times \lambda \times n}{1 - n}$$

where $CT$ denotes the averagae lead time from order receipt to completion of product or service delivery (production lead time), and $T_e$ represents the service time (processing time). If the selling price $p$ is interpreted as the opportunity loss per customer who engages in balking or reneging, the opportunity loss $f(\lambda)$ is calculated as follows:

$$f(\lambda) = p \times \frac{\lambda^2}{\mu^2 - \mu\lambda} \times \frac{n}{1 - n} \qquad (1)$$

Equation (1) explains that opportunity losses increase as queues lengthen and waiting times extend. Banker et al. (2014) did not directly measure or observe congestion costs; however, Balakrishnan and Soderstrom (2000) provide evidence of these costs in obstetrics and gynecology practices. In their study, Balakrishnan and Soderstrom (2000) measure congestion costs as expenditure-based costs observable within conventional accounting systems. In contrast, the congestion costs proposed by Hirai and Kataoka (2024) focus on opportunity losses and foregone profits resulting from customer behavior.

In Hirai and Kataoka's (2024) model, congestion costs increase sharply as utilization rises. The model identifies the sales volume at which marginal revenue equals marginal cost. Assuming

that marginal revenue (i.e., the selling price) remains constant, the optimal sales volume is determined by the condition that the selling price equals the marginal cost, including congestion costs. Once the optimal sales volume is established, the corresponding optimal utilization rate is also ascertained.

Specifically, Hirai and Kataoka (2024) introduce congestion costs into the traditional CVP analysis model, as shown in Equation (2), and propose a new profit function as shown in Equation (3):

$$\tilde{\pi}(x) = (p - a)x - b \qquad (2)$$

$$\tilde{\pi}(x) = (p - a)x - b - p \times \frac{x^2}{\mu^2 - \mu x} \times \frac{n}{1 - n} \qquad (3)$$

Where $\tilde{\pi}$ denotes profit, $p$ is the selling price, $x$ is the sales volume, $a$ is the variable cost per unit, and $b$ represents fixed costs.

The utilization rate corresponding to the optimal sales volume $x^*$, which maximizes Equation (3), is defined as the optimal utilization rate. The processing rate per unit time (i.e., capacity) represents the level of capacity, ensuring that the feasible sales volume does not exceed capacity ($0 \leq x \leq \mu$). Furthermore, the derivative of Equation (3) with respect to $x$, denoted as $\tilde{\pi}'(x)$, represents the opportunity loss per unit (marginal opportunity loss) of product or service arising from the inability to achieve the optimal sales volume $x^*$, that is, from failing to achieve the optimal utilization rate. This per-unit opportunity loss indicates the potential improvement gained by approaching the optimal sales level. Unlike traditional CVP analysis, the new profit function in Equation (3) indicates that there are two break-even sales quantities.

We simplified the simulations in Hirai and Kataoka's (2024) model by fixing variables other than sales volume. This approach emphasizes the effects of changes in specific variables while demonstrating the model's extensibility and applicability to scenarios involving other variable changes. However, Hirai and Kataoka's (2024) model treats price as a constant. Therefore, the research on "demand management through pricing," which originated with Dean (1951), and the "control of congestion costs" based on queueing theory have yet to be integrated into a unified model.

# 3 MODEL SPECIFICATION AND SIMULATION

## 3.1 Model Specification

In this section, we extend Hirai and Kataoka's (2024) model by incorporating a demand function to broaden its applicability.

The Hirai and Kataoka (2024) model presented in Equation (3) assumes that the selling

price $p$, variable cost $a$, fixed-cost equivalent $b$, production capacity $\mu$, and rate of balking or reneging $n$ are constants. It proposes a new profit function in which sales volume $x$ is the explanatory variable and profit is the dependent variable. Therefore, Hirai and Kataoka's (2024) model focuses on how changes in sales volume affect costs and profits.

The major contribution of Hirai and Kataoka's model lies in the incorporation of congestion costs, enhancing its extensibility[1]. By visualizing how changes in each variable affect costs and profits as dependent variables, the model aims to provide insights for managerial decision-making. In profit planning based on the traditional CVP analysis model shown in Equation (2), there is only a single break-even point, with the optimal sales volume corresponding to full capacity utilization. In contrast, Hirai and Kataoka (2024) proposed simulations based on a new profit function that explicitly accounts for congestion costs. This confirms the existence of two break-even points and enables the calculation of both the optimal sales volume and utilization rate.

However, as with traditional CVP analysis, a limitation of Hirai and Kataoka's (2024) model is its assumption that the selling price of products or services remains constant regardless of sales volume. This study addresses this issue by extending the model to incorporate a demand function. Specifically, we introduce a demand function, as shown in Equation (4), in which the selling price $p$ is the decision variable and the sales volume $x$ is the endogenous variable. Here, $d$ represents the maximum willingness to pay for the product or service, and $m$ is a parameter related to price elasticity.

$$x(p) = \frac{d - p}{m} \qquad (4)$$

Next, we transform the demand function in Equation (4) into the inverse demand function $p = d - mx$ and substitute it into Equation (3), which represents the profit function of Hirai and Kataoka's (2024) model, yielding Equation (5).

$$\hat{\pi}(x) = (d - mx - a)x - b - (d - mx) \times \frac{x^2}{\mu^2 - \mu x} \times \frac{n}{1 - n} \qquad (5)$$

When assuming a linear demand curve, price elasticity is given by

$$\varepsilon = (\Delta x/x)/(\Delta p/p) = (\Delta x/\Delta p) \cdot (p/x) = -\frac{1}{m} \cdot \frac{p}{x},$$

indicating a larger value of $m$ corresponds to lower price elasticity.

The selling price $p^*$ that induces the optimal sales volume $x^*$, maximizing $x$ in Equation (5), represents the strategic selling price that the firm should set. Notably, this strategic selling price may vary substantially depending on the parameter $m$, which captures

[1] Although we use the selling price $p$ for simplicity in calculations, it is also possible to use the contribution margin in practical applications and model extensions.

the price elasticity of demand. Accordingly, we present a numerical simulation of Equation (5) in the following section.

### 3.2 Simulation and Findings

In this section, we conduct a simulation using numerical examples with the profit function π(x) that incorporates the demand function (Equation (4)). We compute (i) the optimal sales volume that maximizes profit, $x^*$, along with the corresponding optimal price, $p^*$; and (ii) the break-even sales volume, $x_{BEP}$, and the corresponding break-even price, $p_{BEP}$. The primary objective is to examine how changes in the parameter $m$, which represents price elasticity of demand, affect the profit structure, including congestion costs, and the resulting optimal solutions.

For the numerical simulation, the parameter values are set as follows:

- Maximum willingness to pay for the product/service: $d = 4{,}000$ US dollars
- Parameter related to price elasticity of demand: $m = 0.5,1,1.5,2,2.5,3,3.5$
- Variable cost per unit of product/service: $a = 600$ US dollars
- Fixed-cost equivalent: $b = 200{,}000$ US dollars
- Production capacity: $\mu = 1{,}000$ units
- Rate of balking or reneging: $n = 0.75$

Since the congestion cost term diverges as the denominator $(\mu^2 - \mu x)$ approaches zero, sales volume is evaluated within the range $0 < x < \mu$. Additionally, the condition $p \geq 0$ (non-negative prices) must be satisfied. Specifically, when $m = 4$, the price function becomes $p = 4{,}000 - 4x$, which implies $p \leq 0$ for $x \geq 1{,}000$. Therefore, the simulation results are shown only for the range $x < 1{,}000$.

Figure 1 illustrates how the profit function π(x), based on Equation (5), changes with sales volume $x$ as the parameter $m$ varies from 0.5 to 3.5 under the specified conditions.

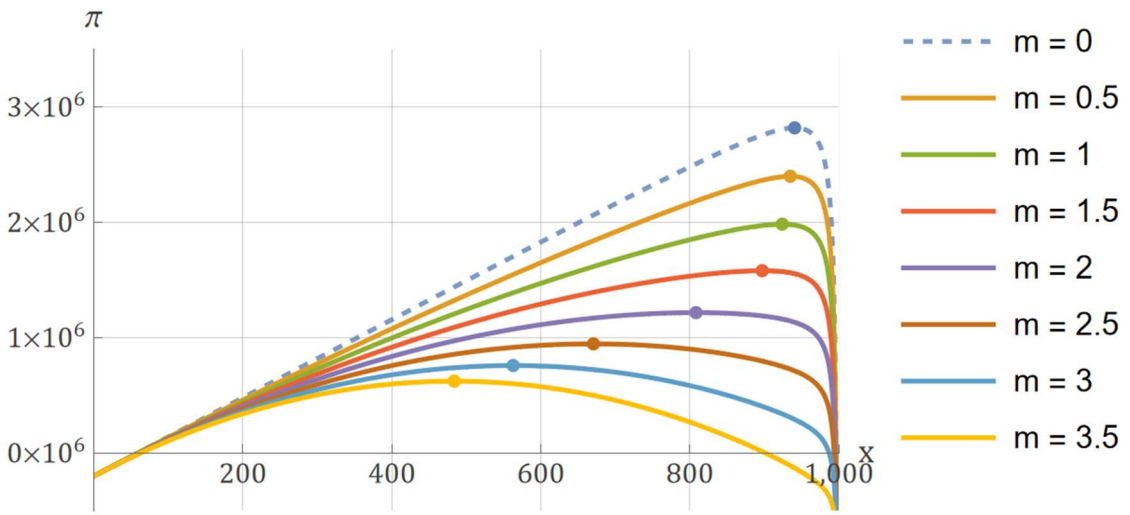


**Figure 1. Relationship between Profit and Sales Volume $x$**

*Note: Dots indicate the optimal sales volume $x^*$.*

The dashed line for $m = 0$ represents Equation (3) with $p = d$ corresponding to Hirai and Kataoka's (2024) model, which does not incorporate a demand function and considers only congestion costs. Each profit curve corresponds to a given value of $m$, with a dot marking a point of profit maximization (i.e., optimal sales volume $x^*$). As $m$ increases from 0.5 to 3.5, the optimal sales volume $x^*$ decreases, leading to a decline in maximum attainable profit.

For comparison with Figure 1, the profit function π(x) with respect to sales volume $x$ when $n = 0$ (excluding congestion costs), is illustrated in Figure 2. The dashed line for $m = 0$ represents Equation (2) with $p = d$, corresponding to the traditional CVP analysis model that does not incorporate a demand function or congestion costs. In Figure 2, profit is maximized at $x = 1{,}000$ for $m = 0.5, 1.0,$ and $1.5$. Even for $m = 2.0$, the optimal sales volume $x^*$ is notably larger than that in Figure 1. By contrast, for $m = 2.5, 3.0,$ and $3.5$, the optimal sales volume $x^*$ does not differ substantially from that in Figure 1. This outcome indicates that a higher price elasticity of demand (i.e., the smaller the value of $m$), amplifies the impact of accounting for congestion costs.

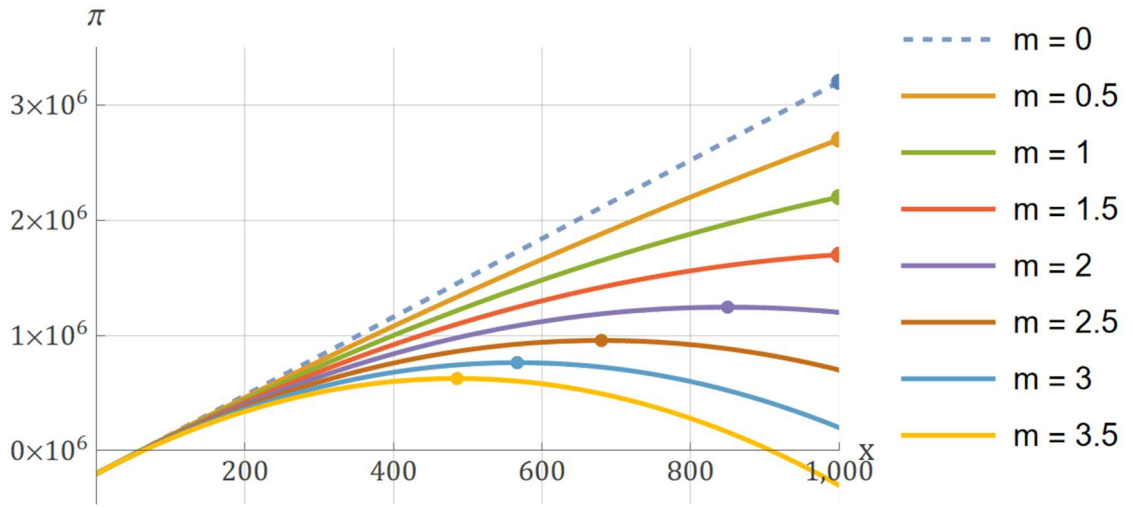


**Figure 2. Relationship between Profit and Sales Volume $x$ (Congestion Cost Not Considered)**

*Note: The dot indicates the optimal sales volume $x^*$.*

To observe this tendency more carefully, how the optimal sales volume $x^*$ changes with respect to $m$ is illustrated in Figure 3. When both congestion costs and the demand function are taken into account, $x^*$ decreases monotonically as $m$ increases. However, this decrease is not linear; rather, the rate of decrease becomes relatively larger in the region where $m$ is high.

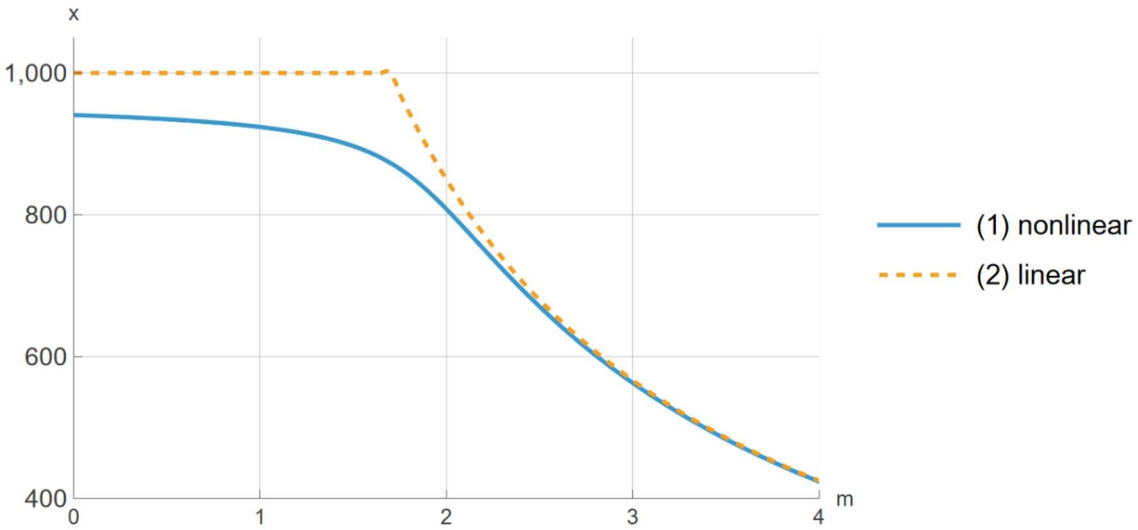


**Figure 3. Relationship between Optimal Sales Volume $x^*$ and Price Elasticity Parameter $m$**

By contrast, when only the demand function is considered, $x^*$ does not decrease until $m$ reaches 1.7, after which it decreases monotonically as $m$ increases. This reflects the results

presented in Figure 2, where profit is maximized at $x = 1{,}000$ for $m = 0, 0.5, 1.0,$ and 1.5.

For reference, Figure 4 illustrates the difference in the optimal sales volume $x^*$ depending on whether congestion costs are considered, for each value of $m$. From Figure 4, we confirm that the difference in $x^*$ reaches its maximum at $m = 1.7$. In the region where $m > 1.7$, the difference in $x^*$ decreases sharply as $m$ increases when both the congestion costs and demand function are considered; however, it does not converge to zero. This indicates that the effect of congestion costs persists even at higher levels of $m$.

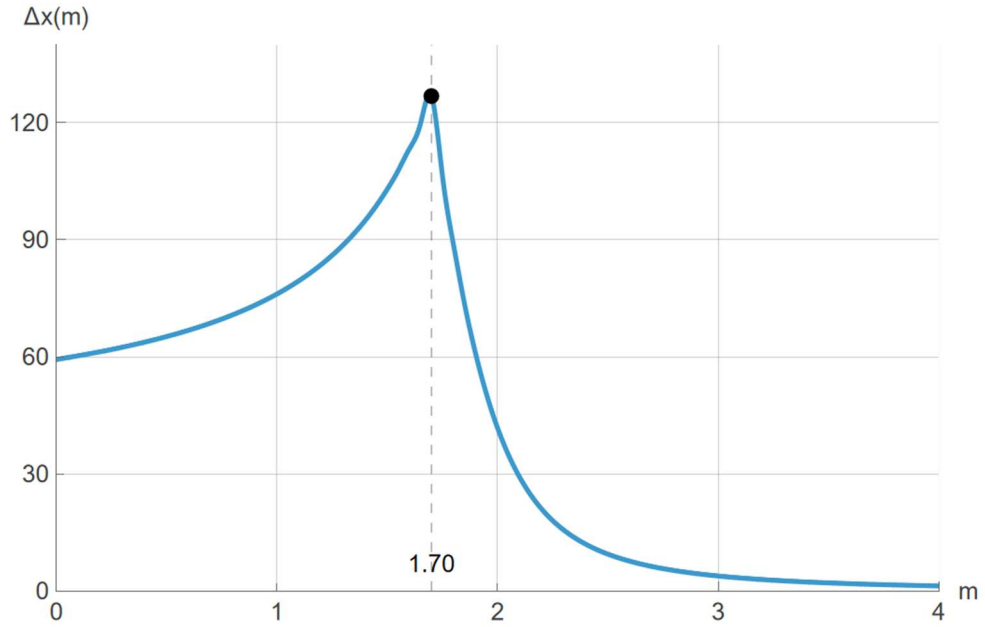


**Figure 4. Difference in Optimal Sales Volume $x^*$ and Price Elasticity Parameter $m$**

Next, for each value of $m$, the optimal sales price $p^*$ that achieves the optimal sales volume $x^*$, together with the corresponding maximum profit $max\ \hat{\pi}$, is presented in Table 1. In this simulation, capacity and the rate of balking or reneging are assumed constant. However, as the parameter related to price elasticity of demand $m$ increases (i.e., as price elasticity decreases), the maximum profit $max\ \hat{\pi}$ declines substantially (from 2,399,356 to 622,564). Concurrently, the optimal sales volume $x^*$ also decreases markedly (from 934.84 to 483.67), and the optimal price $p^*$ reduces from 3,533 to 2,307.

**Table 1. Optimal Sales Volume $x^*$ and Sales Price $p^*$ that Achieve the Maximum Profit $max\ \hat{\pi}$**

| $m$ | $\max \hat{\pi}$ | $x^*$ | $p^*$ |
|---|---|---|---|
| 0.5 | 2,399,356 | 934.84 | 3,533 |
| 1.0 | 1,984,158 | 923.94 | 3,076 |
| 1.5 | 1,580,678 | 897.09 | 2,654 |
| 2.0 | 1,217,154 | 808.27 | 2,383 |
| 2.5 | 946,263 | 670.59 | 2,324 |
| 3.0 | 758,264 | 562.86 | 2,311 |
| 3.5 | 622,564 | 483.67 | 2,307 |

Furthermore, we compute the sales quantities that satisfy the break-even condition $\pi(x) = 0$, denoted as the break-even sales quantities $x_{BEP}$. In our model, which incorporates congestion costs, the profit function is nonlinear; therefore, the break-even point is not necessarily unique, and two break-even points may exist. This is because, in the region of low sales quantities, the firm incurs losses due to the burden of fixed costs, while increasing sales quantities leads to profitability. However, as sales quantities approach capacity and the utilization rate rises, congestion costs increase sharply, potentially causing profits to become negative again.

The simulation reveals two break-even points, $x_{BEP}^{(1)}$ and $x_{BEP}^{(2)}$, for all values of $m$ (Table 2). In addition, the corresponding break-even prices, denoted as $p_{BEP}^{(1)}$ and $p_{BEP}^{(2)}$, associated with each break-even sales volume $\left(x_{BEP}^{(1)} < x_{BEP}^{(2)}\right)$ are reported in Table 2.

**Table 2. Break-even Sales Quantities $x_{BEP}$ and Break-even Prices $p_{BEP}$**

| $m$ | $x_{\mathrm{BEP}}^{(1)}$ | $p_{\mathrm{BEP}}^{(1)}$ | $x_{\mathrm{BEP}}^{(2)}$ | $p_{\mathrm{BEP}}^{(2)}$ |
|---|---|---|---|---|
| 0.5 | 59.4 | 3,970 | 996.1 | 3,502 |
| 1.0 | 59.9 | 3,940 | 995.9 | 3,004 |
| 1.5 | 60.4 | 3,909 | 995.6 | 2,507 |
| 2.0 | 61.0 | 3,878 | 995.0 | 2,010 |
| 2.5 | 61.6 | 3,846 | 993.7 | 1,516 |
| 3.0 | 62.3 | 3,813 | 987.0 | 1,039 |
| 3.5 | 62.9 | 3,780 | 901.4 | 845 |

According to Table 2, congestion costs increase sharply during the rising utilization phase. As a result, profits may fall below zero if sales quantities exceed a certain level. This indicates that a region exists where traditional CVP analysis—"higher utilization leads to higher profit"—does not apply. Specifically, as $m$ increases, the second break-even sales volume $x_{BEP}^{(2)}$ decreases (from 996.1 units when $m = 0.5$ to 901.4 units when $m = 3.5$).

Overall, these simulation results demonstrate that considering both the demand function (the relationship between price and volume) and congestion costs (opportunity losses associated with higher utilization) leads to the following implications:

(i) Two break-even points may exist (as seen when only congestion costs are considered).
(ii) The optimal sales volume and maximum profit are heavily influenced by price elasticity.
(iii) Pricing decisions are based on a trade-off between congestion mitigation and demand acquisition.

# 4 DISCUSSION

This section discusses the implications of the simulation findings for interpreting CVP analysis.

In the simulations, a new profit function (Equation (5)) was modeled by incorporating a demand function that accounts for congestion costs (Equation (3)). We held the intercept of the inverse demand function (d) constant at 4,000 and varied the slope of the demand curve, *m*, from 0.5 to 3.5 to clarify how changes in price elasticity affect firm revenue.

Price elasticity is an indicator of how much the quantity demanded changes in response to a change in price, and its level varies depending on factors such as the availability of substitutes (competing firms) in the market and whether the product or service is a necessity. As previously noted, since *m* represents the slope of the inverse demand function, a smaller value of *m* indicates a situation in which demand is elastic with respect to price (i.e., demand is sensitive to price changes), whereas a larger value indicates a situation in which demand is inelastic with respect to price (i.e., demand is insensitive to price changes).

When price elasticity is low, raising prices tends to increase sales revenue. Firms often adopt high-price strategies and emphasize the added value of their products or services. Conversely, when price elasticity is high, lowering prices typically increases sales revenue. Firms may implement low-price strategies, such as sales promotions, to stimulate demand. In industries where inventory is difficult to hold, firms might maximize revenue by adjusting prices according to demand, supply conditions, time periods, and competitors' prices. They

may also set different prices for distinct customer segments (dynamic pricing). In this context, price elasticity is a critical factor in customer segmentation.

In the simulations in the previous section, as $m$ increased (i.e., as price elasticity decreased), the optimal sales volume $x^*$ decreased and the optimal selling price $p^*$ also decreased, thereby resulting in a decline in maximum profit $max\ \hat{\pi}$. In addition, as $m$ increased, the first break-even sales volume $x_{BEP}^{(1)}$ increased, while the second break-even sales volume $x_{BEP}^{(2)}$ decreased. Consequently, the interval between $x_{BEP}^{(1)}$ and $x_{BEP}^{(2)}$ became narrower. Similarly, both break-even prices $p_{BEP}^{(1)}$ and $p_{BEP}^{(2)}$ declined.

These changes occurred because the intercept of the inverse demand function was held constant while its slope varied. It is important to emphasize that variations in price elasticity impact optimal sales volume $x^*$ and the corresponding selling price $p^*$, and consequently alter the maximum profit $max\ \hat{\pi}$. A related concept is the theory of price discrimination in economics (Pigou, 1932), which describes the behavior of a monopolistic firm that charges different prices for the same product or service to various customer groups or markets. Among the three types of price discrimination, third-degree price discrimination involves segmenting markets based on differences in price elasticity of demand and setting different prices accordingly. This theory is now widely applied through dynamic pricing in various industries, such as airlines, hotels, and theme parks. In this study's context, future applications may involve deriving the optimal sales volume $x^*$, the corresponding selling price $p^*$, and the maximum profit $max\ \hat{\pi}$ in scenarios with multiple customer groups exhibiting different demand curve intercepts (maximum willingness to pay) and varying price elasticities.

The simulations in this study consider congestion costs under the assumption of fixed capacity. Here, the price elasticity discussed refers to short-run price elasticity and serves as an indicator for firms when determining short-run pricing strategies to maximize revenue. From a capacity utilization management perspective, the simulation results suggest that when price elasticity is high (i.e., the value of $m$ is close to 0), utilization rates must be managed carefully to avoid excessive levels. Conversely, when price elasticity is low (i.e., the value of $m$ is high), it suffices to maintain utilization at a generally appropriate level. In both scenarios, appropriate price control is crucial.

Finally, while the simulations in this paper assume a constant rate of balking or reneging, this rate may differ among customer groups with varying price elasticities. The rate of balking or reneging is also likely to vary based on the market characteristics discussed above. By considering these various market factors, strategically setting selling prices can help control demand (sales volume) to maximize profits or meet profit targets. This approach may ultimately help smooth demand over time.

# 5 CONCLUSIONS

The simulations in this study demonstrate that markets should be segmented by differences in price elasticity and that appropriate pricing strategies must be implemented for each segment.

As discussed in Section 2, traditional CVP analysis was initially proposed as a technique for short-term profit planning. However, with Dean's (1951) introduction of demand functions, the CVP analysis model evolved into a decision-making tool focused on profit maximization. Lau and Lau (1987) clarified the impact of selling prices on profit and loss calculations, positioning selling price as a variable that managers should strategically control.

Contemporary society faces multiple challenges, such as over-tourism, hospital bed shortages, severe traffic congestion, and constraints on power generation due to excessive electricity demand, making capacity expansion in response to demand difficult. Consequently, unresolved issues remain. It is essential to incorporate congestion costs, arising from the relationship between capacity and demand, into CVP analysis. This extension is also vital for addressing modern managerial challenges, including dynamic pricing, which aims to maximize profits while managing demand.

The model developed in this study advances traditional CVP analysis into a strategic CVP analysis model that supports managers in strategically managing selling prices. While segment-based profitability analysis and pricing are necessary, appropriate pricing decisions cannot be made without properly reflecting congestion costs. In modern revenue management, emphasizing market segmentation based on price elasticity of demand and implementing differentiated pricing strategies across segments is critical (Huefner, 2011; Kataoka, 2024). By applying the model proposed in this study, the precision of differentiated pricing can be improved, and profit maximization can be pursued while controlling the congestion costs that may arise within each segment.

This study highlights the importance of adopting a proactive pricing stance rather than a passive view in which prices are determined by the market. Firms should strategically set prices to control demand and achieve profit maximization in each segment. While firms in regulated industries may be more likely to take the initiative in price setting, even in non-regulated or highly competitive markets, firms must continuously develop and provide products and services that leverage their strengths and enhance customer value. From this perspective, applying a strategic CVP analysis model is highly beneficial for contemporary revenue management.

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