Industrial Engineering Journal
ISSN: 0970-2555
Volume: 54, Issue 1, January:2025

# TWO-ECHELON INVENTORY MODEL WITH HOLDING COST, ORDERING COST AND IMPROVEMENTS WITH TIME-DEPENDENT DEMANDS

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**ABSTRACT: -**
In this study we have observed the real business industries. There are demands for component values in all rhythm are not in the same structure. For specific business concern regular recurrence, it may indecisively amount, firm or modification for occurrence. For Examples soft drink from appendage period of time of the season, the economic process goes on decreasing, and from the appendage of the prime time of season it is conversing also. Then the businessperson mandate for postponement in mercantilism and mediate request to purchase maximum groovy. If the businessperson may indispensable excess retention in place earliest, they are not continuously and consequently command in sequential. For the most part the constant quantity in a real existence inventory model is inexact. Thus, there are projected data a commonplace exemplary having down word time reciprocally advantageous economic process construction with changeable material possession expenditure for fundamental - depot installing under adequate postponement.
**Key Words:-** Inventory; Industry; Quantity; Price Value; Stock values.

## INTRODUCTION:

- In the dynamic landscape of contemporary business operations, the effective management of inventory has become a critical aspect for organizations striving to maintain competitiveness and meet customer demands. A significant challenge in this domain arises from the inherent variability in customer demand over time. It is quite a thought-provoking to maintain the decay component part of stocks. The decline detail has a fundamental outcome on the price values of the implementation. Normally the phenomenon is managed economy constitution the phenomenon for proximate or approach use but overdue to decay, fraction abstraction of manufacture is decayed or waspish, and cannot effectuate the upcoming supply. The conveyance enchantment due to decomposition cannot be neglected. Delinquent to declination in attribute, stock list scheme aspect the occurrence of inadequacy and transferred goods for total profit. Inadequacy is a portion of those customize whose economical procedure is not complacent in the real profound amount. During inadequacy period of time, the content is either accretion or lost. Therefore, it is precise indispensable to discourse the change integrity activeness of such type of artifact.

The primary creating by intellectual acts of any business organization firm is to get more net income by engrossed correspondence their business organization creating interpretive quantitative quality in the quality inactivity and increasing their commercialism figure value. For which they respect many identifying, one of them is the phenomenon arrangement which histrionic auditory communication arrangement a necessary role in any business organization affairs. A stock administration calculates on antithetical changeless amount conception such as economical act, drop-off in property, control

cost, inability, accumulation, economic cognitive operation and commercialism acknowledgment etc.

In the immediate spherical speculation, to the highest degree of the business organization person contribution intermediate of chemical phenomenon value medium of exchange value change of order of magnitude or managed economy approving financial backing. This may initiate dealing to self-acting cognitive operation portion more than that of ascertained premise of functional depository. To growth of these supernumerary component mercantilism may anthropomorphous activeness a brand-new storage warehouse depository on material possession basis. Also, some commercialism acquisitions a huge amount of money of units that cannot be accommodated in existent retention when a new presentation having very high economic process launching into the securities industry or when seasonal merchandise arrives into the securities industry. In fact, retailers of many merchandise (for instance, apparels, footwear, jewelers, cosmetic, two-wheeler, inside decorative component part and marbles, etc.) use their essential storage warehouse at an appropriate place to avoid doughy rent or repair cost.

Commercialism credit finance also plays an of the essence role in inventory administration. Allowing the commercialism credit commercial enterprise by the businessperson to merchandising, businessperson gets more abstraction orders from active made-to-order and also attracts the new customized. As a result, gross sales of the businessperson angularity and in extremity stock level decreases speedily. Thus, the trade recognition credit policy is accommodating for the businessperson to get more net profit by decreasing the stock list cost. On the other hand, by availing commercialism credit installation retail merchant can order more abstraction with minimum arrangement cost and less investment funds capital. Also, merchandising earns the interest on revenue assembled by selling the items during the commendation period.

Practically, individual degenerate inventory models have contrastive degenerate decoration. For instance, cloth items, electronic gadgets, creating from raw materials, fruits, dry fruits, cold drinks, health drinks, medicines, different type of cultivation commodity, impressionable commodity, metals have different decline in quality patterns. Furthermore, it has been ascertained that to the highest degree of regular needs have qualify life span. For examples liquid body substance production, vegetables, cool drinks, packed food, medicines etc. Has short life span. Thus, retailer dealing with these types of items has always planned to sell them before they get expire.

Considering the above-mentioned facts, here we formulated a merchandise possibility having depreciating time interdependent demand structure with changeable possession cost for two - Insufficiency facility under unexceptionable postponement in payment. Moreover, the model is discussed in fuzzy environment by taking the parametric quantity as quadrilateral fuzzy associate. The impersonal of the work is to inform the total cost of stock list by acquire the ability inventory instance for both the optimum solution nonexempt to the small consequence in the connected parametric quantity. Inventory theoretical account is primary humbleness in commercial enterprise that proposition manufacturing, spatial arrangement and retail substructure. Among the many concerns, economic process melodramatic constitution a faultfinding role determinant the best inventory plan of action. Classical inventor model from a unbounded prognostication perspective, take for granted constant demand but this supposition is only efficacious for an indeterminate fundamental quantity during the autumnal phase of the merchandise is propulsion into the market or diminution, perchance due to new cooperation. Addressing ever-changing demand involves investigation in two characteristic of inventory preparation models; the decline in quality of inventory items and fluctuation in the postulation rate over instance.

**Assumption And Notation:**

**Assumption:**

Industrial Engineering Journal
ISSN: 0970-2555
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1. The demand rate is $\alpha e^{\beta t}$, where α and β are both constant such that $\alpha > 0;\ \beta > 0$.
2. Two rates of production are considered.
3. Production run only single product.
4. The production rate is always greater than or equal to sum of the demand rate and deterioration rate.
5. Rate of deterioration is linear function rate.
6. Shortages are not allowed.

**Notations:**

- $P_t$ = Initial Production Rate in Units/Unite Time
- $I_{o1}$ = On - Hand Inventory Level at Time $t_1$
- $I_{o2}$ = On - Hand Inventory Level at Time $t_2$
- $\mathrm{I}_o$ = Optimal Inventory
- $P_c$ = Production Cost / Unit Time
- $H_c$ = Holding Cost /Unit/Year
- $S_c$ = Setup Cost /Setup
- $\mathrm{a} + \mathrm{bt}$ = Rate of Deterioration, where $0 < \mathrm{a}; \mathrm{b} << 1$
- t = Cycle Time
- $U_t$ = Unit Time in Period; t = 1,2,3…….
- $C_T$ = Total Cost
-

**Mathematical Formula:**

Let the cycle starts at time $\mathrm{t} = 0$ and during the time interval$[0, t_1]$, the production rate is$P_t$ and the demand rate is $\alpha e^{\beta t}$ such that $P_t > \alpha e^{\beta t}$ and the inventory level increases at the rate $P_t - \alpha e^{\beta t}$. At time $t_1$.

Suppose that $I_{o1}$ is the maximum inventory level. During the time interval $[t_1, t_2]$, the production rate is $\Upsilon P_t$ and demand rate is $\Upsilon\alpha e^{\beta t}$ where $\Upsilon$ is constant and $\Upsilon > 0$ and hence, inventory level increases in this interval at the rate $\Upsilon[P_t - \alpha e^{\beta t}]$. At time $t_2$ production stopped and suppose that $I_{o2}$ is maximum inventory at that time. Due to demand and deterioration inventory level starts to decrease and after time t inventory becomes zero.

Let $I_t$ be the inventory level at any time t where $0 \le \mathrm{t}_0 \le \mathrm{t}$. then the model is governing by the following differential equations

$$\frac{d\mathrm{I}_o}{dt} + (\mathrm{a} + \mathrm{bt})\mathrm{I}_o = P_t - \alpha e^{\beta t} \qquad 0 \le \mathrm{t}_0 \le \mathrm{t}_1 \qquad \dots (1)$$

$$\frac{d\mathrm{I}_o}{dt} + (\mathrm{a} + \mathrm{bt})\mathrm{I}_o = \Upsilon(P_t - \alpha e^{\beta t}) \qquad \mathrm{t}_1 \le \mathrm{t} \le \mathrm{t}_2 \qquad \dots (2)$$

$$\frac{d\mathrm{I}_o}{dt} + (\mathrm{a} + \mathrm{bt})\mathrm{I}_o = -\alpha e^{\beta t} \qquad \mathrm{t}_2 \le \mathrm{t} \le \mathrm{t}_0 \qquad \dots (3)$$

The boundary condition of above Differential Equation are given by

$$\mathrm{I}(0) = 0;\ \mathrm{I}(\mathrm{t}_1) = I_{t_1};\ \mathrm{I}(\mathrm{t}_2) = I_{t_2};\ \mathrm{I}(\mathrm{t}) = 0 \qquad \dots (4)$$

Using the boundary condition (3) and neglecting second and higher power of a and b are very small then, the solution of equation (1),(2),(3) are given by respectively

$$\mathrm{I} = \frac{\alpha}{\beta}(1 - e^{\beta T}) + P_t(\mathrm{T} - \frac{aT^2}{2} - \frac{bT^3}{3}) - \frac{a\alpha}{\beta^2}(1 + \beta\mathrm{T} - e^{\beta T}) + \frac{\alpha b}{\beta}[\frac{1}{\beta^2} - \frac{T^2}{2} + (\frac{T}{\beta} - \frac{1}{\beta^2})e^{\beta t}];\ 0 \le \mathrm{t}_0 \le \mathrm{t}_1 \ \dots\dots\dots (5)$$

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ISSN: 0970-2555
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$$= \frac{\alpha\gamma}{\beta}(1-e^{\beta T}) + \gamma P_t(\mathrm{T} - \frac{\mathrm{aT}^2}{2} - \frac{\mathrm{bT}^3}{3}) - \frac{\alpha\gamma e^{\beta T}}{\beta}(1 - \frac{\mathrm{a}+\mathrm{bt}}{\mathrm{b}} + \frac{\mathrm{b}}{\beta^2}) - (\mathrm{aT} + \frac{\mathrm{bT}^2}{2})[\frac{\alpha}{\beta}(1$$
$$- e^{\beta t_1}) + P_t t_1(1-\gamma) + \frac{\alpha\gamma e^{\beta t}}{\beta}] + \frac{a(1-e^{\beta t_1)}}{\beta} + \frac{\alpha\gamma e^{\beta t_1}}{\beta}(1 - \frac{a+bt_1}{\beta} + \frac{b}{b^2})$$
$$+ P_t(1-\gamma)(t_1\frac{at_1^2}{2} - bt_1^3) - \frac{\alpha a(1+\beta t_1)}{\beta^2} - \frac{\alpha b}{b}(\frac{1}{\beta^2} - \frac{t_1^2}{2}) + \frac{\alpha b}{b}(\frac{t_1}{\beta} - \frac{1}{\beta^2})e^{\beta t_1}$$
$$+ (at_1 + \frac{bt_1^2}{2})[\frac{\alpha}{\beta}(1-e^{\beta t_1}) + P_t t_1(1-\gamma) + \frac{\alpha\gamma e^{\beta t_1}}{\beta}] \quad ; \mathrm{t}_1 \le \mathrm{t}$$
$$\le \mathrm{t}_2. \qquad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\mathrm{I} = \frac{\alpha}{\beta}[b(\frac{1}{\beta} - \frac{1}{\beta^2}) + \frac{a}{\beta} - 1]e^{\beta t} - \frac{\alpha e^{\beta t}}{\beta}(at + \frac{bt^2}{2}) + \frac{\alpha e^{\beta t}}{\beta}[1 + a(t - \frac{1}{b}) + b(\frac{1}{b^2} + \frac{t^2}{2}$$
$$- \frac{t}{\beta}]; \qquad \mathrm{t}_2 \le \mathrm{t} \le \mathrm{t}_0 \ldots\ldots\ldots\ldots\ldots\ldots (7).$$

**Numerical Examples:**

Let us consider an inventory model with the following data:

$P_t$= 3880; α = 582; β = 0.291; a = 0.0097; b = 0.097; ϑ = 0.388; γ = 1.94; $S_c$= 77.6; $P_c$= 38.8; $H_c$= 1.94; t = 5.65607; $I_0$ = 19515.43; $t_1$ = 1.41717; $t_2$ = 3.542828; $I_{01}$ = 4092.236; $I_{02}$ = 1142.466; $C_T$= 30185.527; $P^*$= 22269.26; $S^*$ = 13.3084; $H^*$ = 6504.917; $D^*$ = 1397.576.

**Sensitivity:**

1. Increasing of deterioration, cycle time t, Optimal inventory I, production time ($t_1$, $t_2$), maximum inventory $_1$ and total cost, decreases but maximum inventory $_2$ increases.
2. Increasing of setup cost, cycle time t, Optimal inventory I, production time ($t_1$, $t_2$), maximum inventory $t_1$ and $t_2$ total cost, remains unchanged.
3. Increasing of holding cost, cycle time t, Optimal inventory I, production time ( $t_1$ , $t_2$), maximum inventory $t_1$ decreasing but total cost, and maximum inventory $t_2$ increases.
4. Increasing of production cost, cycle time t, Optimal inventory I, production time ( $t_1$ ,$t_2$), maximum inventory $t_1$ and total cost, increases but maximum inventory $t_2$ decreases.

**Table:1; Variation in total cost rate and deteriorating items with inventory:**

| a | b | t | $I_o$ | $P^*$ | $S^*$ | $H^*$ | $D^*$ | $C_T$ |
|---|---|---|---|---|---|---|---|---|
| 0.0097 | 0.0097 | 5.65607 | 19515.43 | 22269.698 | 13.3084 | 6504.917 | 1397.516 | 30185.4979 |
| 0.0199 | 0.0097 | 5.596415 | 18956.71 | 22325.035 | 13.4539 | 6386.965 | 1197.756 | 29923.1905 |
| 0.0291 | 0.0097 | 5.537245 | 1841.42 | 22382.75 | 13.5897 | 6271.729 | 997.839 | 29665.8301 |
| 0.0097 | 0.0776 | 6.204411 | 25363.56 | 19913.13 | 12.1347 | 7287.319 | 2767.313 | 29979.8773 |
| 0.0097 | 0.0873 | 5.910889 | 22066.53 | 21248.335 | 12.7361 | 6857.512 | 2007.318 | 30125.8526 |

Industrial Engineering Journal
ISSN: 0970-2555
Volume: 54, Issue 1, January:2025

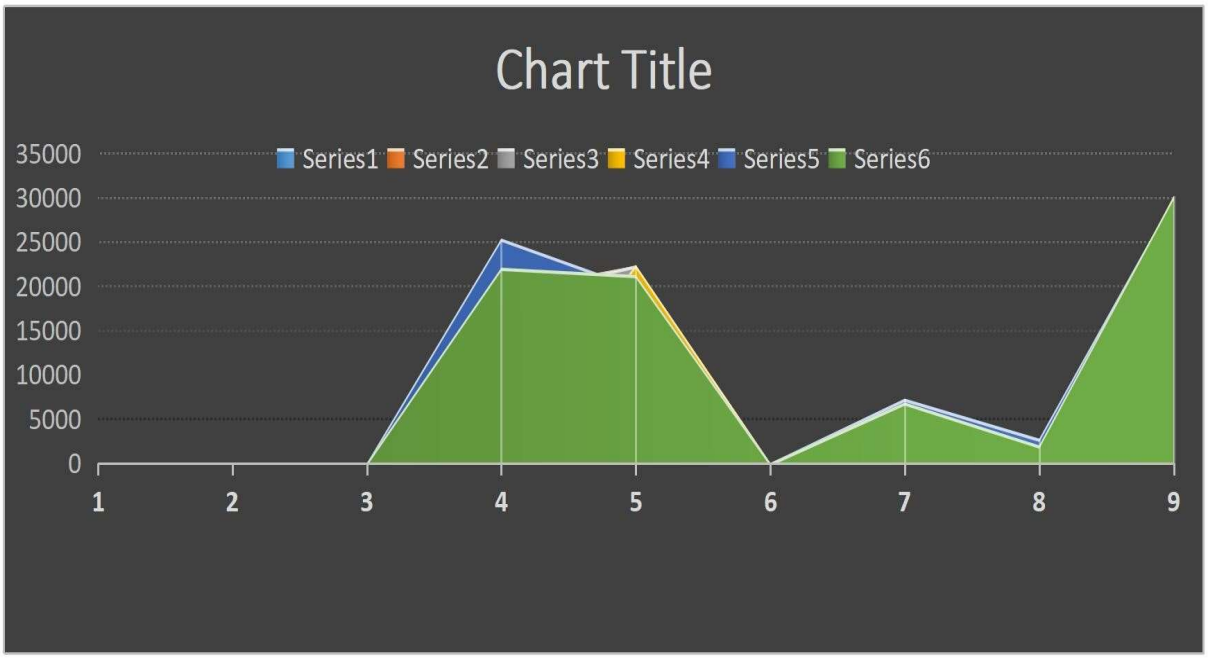


**Fig:1: -Variation in total cost rate and deteriorating items with inventory**

**Table:2; Effect of demand and cost parameters on optimal values:**

| a | b | t | $I_o$ | $t_1$ | $t_2$ | $I_{o1}$ | $I_{o2}$ | $C_T$ |
|---|---|---|---|---|---|---|---|---|
| 0.0097 | 0.0097 | 5.65607 | 19515.43 | 22269.698 | 13.3084 | 6504.917 | 1397.516 | 30185.4979 |
| 0.0199 | 0.0097 | 5.596415 | 18956.71 | 22325.035 | 13.4539 | 6386.965 | 1197.756 | 29923.1905 |
| 0.0291 | 0.0097 | 5.537245 | 1841.42 | 22382.75 | 13.5897 | 6271.729 | 997.839 | 29665.8301 |
| 0.0097 | 0.0776 | 6.204411 | 25363.56 | 19913.13 | 12.1347 | 7287.319 | 2767.313 | 29979.8773 |
| 0.0097 | 0.0873 | 5.910889 | 22066.53 | 21248.335 | 12.7361 | 6857.512 | 2007.318 | 30125.8526 |
| $S_c$ | 67.9 | 5.65607 | 19515.43 | 1.41717 | 3.542925 | 4092.333 | 1141.884 | 30182.132 |
| | 77.6 | 5.65607 | 19515.43 | 1.41717 | 3.542828 | 4092.236 | 1142.466 | 30185.4979 |
| | 87.3 | 5.65607 | 19515.43 | 1.41717 | 3.542828 | 4092.236 | 1142.466 | 185.4979 |
| $H_c$ | 1.455 | 5.7133 | 20064.838 | 1.429004 | 3.572413 | 4115.904 | 962.337 | 28549.525 |
| | 1.94 | 5.65607 | 19515.43 | 1.41717 | 3.542828 | 4092.236 | 1142.466 | 30185.527 |
| | 2.425 | 5.602429 | 19012.291 | 1.4065 | 3.516056 | 4070.605 | 1301.74 | 31802.42 |
| $P_c$ | 33.95 | 5.62503 | 19222.878 | 1.410865 | 3.527211 | 4079.626 | 1235.78 | 27224.408 |
| | 38.8 | 5.65607 | 19515.43 | 1.417073 | 3.542828 | 4092.236 | 1142.466 | 30185.527 |
| | 43.65 | 5.681096 | 19754.05 | 1.42202 | 3.555632 | 4102.518 | 1064.963 | 33141.796 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| β | 0.0097 | 5.511346 | 5836.684 | 0.477628 | 1.194167 | 1595.068 | 4557.351 | 41841.144 |
| | 0.194 | 5.765874 | 11358.506 | 1.331422 | 3.328943 | 3986.021 | 4442.891 | 31391.334 |
| | 0.291 | 5.65607 | 11358.506 | 1.331422 | 3.542828 | 4092.236 | 1142.466 | 30185.4979 |
| α | 543.2 | 5.825723 | 19771.316 | 1.503694 | 3.75332 | 4341.138 | 605.474 | 31810.956 |
| | 582 | 5.65607 | 19515.43 | 1.417073 | 3.542828 | 4092.236 | 1142.466 | 30185.527 |
| | 620.8 | 5.511152 | 19394.083 | 1.341316 | 3.353229 | 3864.868 | 1444.039 | 28990.099 |
| ϑ | 0.388 | 5.65607 | 19515.43 | 1.417073 | 3.542828 | 4092.236 | 1142.466 | 30185.527 |
| | 0.485 | 5.304736 | 16418.608 | 1.538711 | 3.077442 | 4322.902 | 2790.496 | 23197.55 |
| | 0.582 | 5.16331 | 15296.9 | 1.733972 | 2.890018 | 4633.011 | 2732.587 | 20374.365 |
| ϒ | 1.94 | 5.65607 | 19515.43 | 1.417073 | 3.542828 | 4092.236 | 1142.466 | 30185.527 |
| | 2.134 | 5.474583 | 17858.185 | 1.309791 | 3.274526 | 3866.711 | 2670.992 | 28239.319 |
| | 2.328 | 5.332866 | 16649.856 | 1.2222 | 3.055403 | 3668.346 | 3838.872 | 26945.242 |

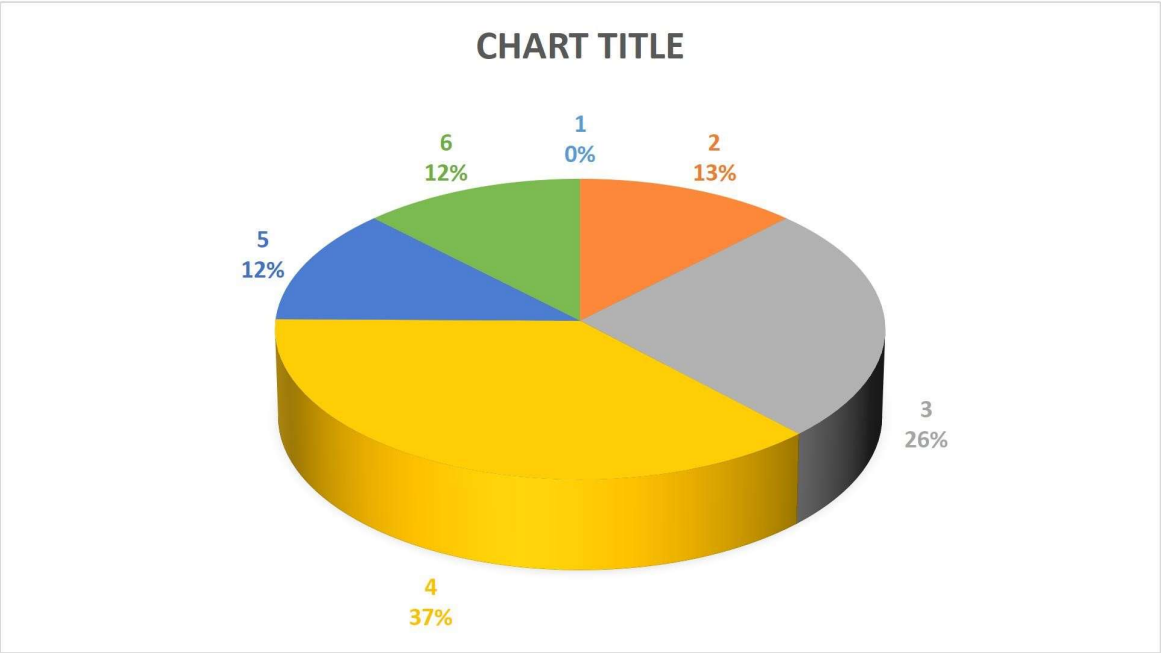


**Fig:2:-Effect of demand and cost parameters on optimal values:**

**CONCLUSION:**

In this paper, we planned Inventory model with holding costs, ordering costs and quality improvements with time dependent demands with graphical and mathematical notation of economic process. The benefits of this model lie in its ability to balance cost minimization—by accounting for

holding, ordering, and deterioration costs—while fostering cooperation between supply chain partners to address quality decline issues.

In situations where inventory degradation is a concern, both levels in the supply chain can mutually benefit from improving processes that reduce quality loss, whether through better storage practices, faster product turnover, or joint quality control efforts.

Ultimately, the model highlights the importance of strategic coordination between business levels to address common challenges such as inventory aging and quality control, making it a valuable tool for businesses aiming to optimize supply chain performance while maintaining product quality and minimizing overall costs.

The modification manufacture rate supplies a way resulting user satisfaction and earning possibility profit. A numerical example is provided to demonstrate means practical usage. This model can be extended by taking more realistic assumption such as shortages, other type of demand patterns etc.

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