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Construction of a Decision Making Index for Inventory Management using Distribution of Price Elasticity of Demand for Perishable Products

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Abstract: **Companies or industries continuously seek innovation in their decision making processes to provide satisfactory service to their customers for survival in the globally competitive market. The objective of the present paper is to construct a decision making index for inventory management using distribution of price elasticity of demand for perishable products. The probability density function of the above distribution has been derived for the statistical application. The numerical value of the proposed index lies between 0 and 1. The magnitude of the index indicates the degree of utilization of inventory consisting of perishable items together with customer's satisfaction. The suggested index will strike the balance between the sale of the product and the level of customer's satisfaction. The application of the suggested decision making index has been illustrated with the help of numerical example.**

Keywords: **decision making index, price elasticity of demand, perishable items.**

1. INTRODUCTION

In order to cope with the competitive market, the companies or the industries are constantly indulged in taking innovative steps to improve their decision making processes so that they provide satisfactory services to their customers and this is essential for their existence in the globally competitive market. This objective can be achieved either by developing inventory models well suited for the practical situations or by developing a decision making index which will be helpful to assess the situation and to take decision accordingly by the management.

In this regard the concept of price elasticity of demand see (Kumar and Sharma (1998)) plays an important role. Price elasticity of demand measures the change in demand as a result of change in price factor. The application of price elasticity of demand in the development of inventory models is seeking the attention of researchers and some of them are continuously involved in the development of inventory models by taking price elasticity of demand.

Price elasticity of demand can be a useful tool for management to make crucial decisions like deciding the price of goods and services. Different products exhibit different elasticity, which in turn, has an influence on a firm's price decisions. In the present paper, we have developed a decision making index for perishable product using distribution of price elasticity of demand. Perishable good is any product in which quality deteriorates due to environmental conditions through time, such as meat and meat by- products, dairy products, fruits and vegetables, flowers, pharmaceutical products and chemicals etc.

Perishable goods have mostly inelastic demand (price elasticity of demand lies between 0 and 1), because there are less substitute and they have to be consumed more quickly. The proposed index , apart from its utility for perishable products can also be used for the essential goods, such as salt, sugar, match boxes and soap etc. for which it is relatively inelastic (less than unity). Inelasticity implies that consumers purchase the same quantity of these goods regardless of the increase or decrease in their prices. Moreover, the consumption of necessities cannot be postponed; therefore the demand for necessities is inelastic.

The main objective of the present paper is to construct a decision making index for inventory management using distribution of price elasticity of demand for perishable products. There does not exist any literature regarding the development of such types of indices. However, Srivastava and Gupta (2007) have constructed a decision making index for inventory system using demand and lead-time distributions. Deriving motivation from the above derivation, we, in the present paper have constructed a decision making index which indicates the degree of utilization of inventory consisting of perishable products together with customer's satisfaction. The development of the index is an effort in this direction.

This objective has been achieved in two ways:

Firstly, we have developed the mathematical index. Secondly, the decomposition of the suggested index has been done on the basis of the parameters of the distributions. For this purpose, the truncated distribution of the observations having price elasticity of demand less than R* has been derived.

Section 2 of the paper deals with the development of the mathematical index while section 3 deals with the derivation of the index using the probability distribution of price elasticity of demand. The application of the index is done in section 4.

2. DEVELOPMENT OF MATHEMATICAL INDEX

Let 'n' be the number of times, the management reviews the price elasticity of demand for the perishable products at regular intervals of time. We have considered the percentage change in demand with respect to percentage change in price and obtain the ratio known as price elasticity of demand denoted by R. let the management specifies the price elasticity of demand to be R* above which the management and customers both are satisfied with the system. Generally, decisions for the betterment of the system are taken on the basis of mean and variance. For that purpose, mean and variance of the distribution of price elasticity of demand for the products in regular interval of time are to be determined. The construction of index based on mean and variance of all 'n' reviews of the price elasticity of demand for the products cannot be considered as satisfactory criteria for taking decision.

Therefore, we have to focus on those observations whose price elasticity of demand is less than R*. These are the cases where either management is not satisfied with the demand of the customer or the customer is also not satisfied with the pricing policy of the products. Thus, decisions based on these observations will provide a firm basis for the construction of efficient index for making decisions.

Now an attempt is made to derive a general decision making index based on price elasticity of demand distribution. For that purpose, we have a sample data of 'n' observations of change in demand with respect to the change in price.

% change in demand $D: D_1, D_2, ..., D_{n_0}, D_{n_0+1}, ...D_n$

% change in price $P: P_1, P_2, ..., P_{n_0}, P_{n_0+1}, ...P_n$

Now, we consider the price elasticity of demand for all the observations and for convenience; these price elasticity of demands are arranged in ascending order.

$$R = \frac{D}{P} : \frac{D_1}{P_1} < \frac{D_2}{P_2} < .... < \frac{D_{n_0}}{P_{n_0}} < \frac{D_{n_0+1}}{P_{n_0+1}} < .... \frac{D_n}{P_n}$$

where $R_i = \frac{D_i}{P_i}$ is the i^{th} price elasticity of demand.

Suppose the management specifies the minimum price elasticity of demand say R* above which the management and the customers both are satisfied with the system.

Let 'n_0' be the number of cases for which price elasticity of demand is less than R*. now it is worthy to consider the partitioned vector having the values less than R*. All the observations whose values are greater than R* will not be the part of the development of the index since in such cases management and the customers both are satisfied with the system.

i.e. $$\underset{\sim}{R}_{n_0} = \begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_{n_0} \end{pmatrix}$$

Let $$\underset{\sim}{d}^* = \begin{pmatrix} d_1 \\ d_2 \\ \vdots \\ d_{n_0} \end{pmatrix} ; \quad \text{where} \quad d_i = \frac{R_i}{R^*}$$

Now consider $\underset{\sim}{w}^* = \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix}$ are the weights attached to $\underset{\sim}{d}_i'^*$ such that $\underset{\sim}{d}'^* \underset{\sim}{w}^*$ determine the index.

Therefore, the general form of the index is

$I = \phi \sum_{i=1}^{n_0} \underset{\sim}{d}'^* \underset{\sim}{w}^*$, where ϕ be the normalizing parameter.

Now $$I = \phi \sum_{i=1}^{n_0} \frac{R_i}{R^*} w_i \qquad (2.1)$$

Let us take

$$w_i \propto \frac{R_i}{R^*}$$

$$\therefore \qquad w_i = k \frac{R_i}{R^*} \qquad (2.2)$$

Where k is the constant of proportionality, which is determined by the condition, that sum of the weights is equal to 1.

Taking summation on both the side of equation (2.2)

$$\sum_{i=1}^{n_0} w_i = k \sum_{i=1}^{n_0} \frac{R_i}{R^*}$$

Since sum of the weights is equal to unity, i.e.

$$1 = k \sum_{i=1}^{n_0} \frac{R_i}{R^*}$$

$$\therefore \quad k = \frac{R^*}{\sum_{i=1}^{n_0} R_i}$$

$$\therefore \quad w_i = \frac{R_i}{\sum_{i=1}^{n_0} R_i} \qquad \text{(from 2.2)}$$

$$\therefore \quad I = \frac{\phi}{R^*} \frac{\sum_{i=1}^{n_0} R_i^2}{\sum_{i=1}^{n_0} R_i} \qquad \text{(from 2.1)}$$

Now only ϕ has to be determined. To determine the normalizing parameter ϕ, consider the case $R_i \le R^{**}, \ i = 1, 2, \cdots, n_0$. where R^{**} is assumed to very small price elasticity of demand. This is the worst possible situation for both the management and customers and practically this situation does not hold.

In this situation, we assume the value of the index to be maximum. Let the maximum value of index I=1, where all R_i's are equal to R**.

$$\therefore \quad 1 = \phi \frac{R^{**}}{R^*}$$

$$\therefore \quad \phi = \frac{R^*}{R^{**}}$$

Hence the index comes to be,

$$I = \frac{1}{R^{**}} \frac{\sum_{i=1}^{n_0} R_i^2}{\sum_{i=1}^{n_0} R_i} \qquad (2.3)$$

The index has been derived for 'n_0' cases having price elasticity of demand is less than R*. Index will take minimum value I=0 when no such cases are there i.e. n_0 is zero. It implies that management and customers both are fully satisfied with the system. The index will take maximum value I=1 which indicates that customers are not satisfied with the pricing policy of the management system and also the management is not satisfied with the demand of the customers. In between 0 and 1, the index indicates different magnitudes for different situations which show the balance between the sale of the products and the level of customer's satisfaction.

The numeric value of the proposed index is useful for management to take the better decision for improving the particular system.

3. DERIVATION OF THE INDEX USING THE PROBABILITY DISTRIBUTION OF PRICE ELASTICITY OF DEMAND

The index I can also be decomposed as,

$$I = \frac{1}{R^{**}} \frac{\sum_{i=1}^{n_0} \left[\left(R_i - \bar{R}_{n_0} + \bar{R}_{n_0} \right) \right]^2}{\sum_{i=1}^{n_0} R_i}$$

$$I = \frac{1}{R^{**}} \frac{s^2_{\underset{\sim}{R}_{n_0}} + \bar{R}^2_{n_0}}{\bar{R}_{n_0}} \qquad (3.1)$$

Where $\bar{R}_{n_0}$ and $s^2_{\underset{\sim}{R}_{n_0}}$ are the mean and variance of $\underset{\sim}{R}_{n_0} = \begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_{n_0} \end{pmatrix}$

Let the demand be Exponentially distributed with probability density function,

$$f(D) = \theta e^{-D\theta} \qquad ; \; D \geq 0$$

where θ is the demand rate.

and the price be distributed as Gamma distribution with probability density function,

$$f(P) = \frac{e^{-P} P^{\lambda-1}}{\Gamma\lambda} \qquad ; \quad P \geq 0$$

where λ is the average price of the product.

Then by applying the transformation of the random variables (see Feller(1970)) we have derived the probability density function of price elasticity of demand as

$$f(R) = \frac{\theta\lambda}{(1+R\theta)^{\lambda+1}} \qquad ; \quad 0 \leq R \leq \infty$$

where θ be the demand rate and λ be the average price.

Since in the construction of the index we are discarding the values above R^* therefore, the truncated probability density function of R at the point $R = R^*$ is given by (see Rohatgi (1976))

$$g(R) = \frac{f(R)}{P(R < R^*)} \quad , \quad R < R^*$$

$$\therefore \; P(R < R^*) = \int_0^{R^*} \frac{\theta\lambda}{(1+R\theta)^{\lambda+1}} dR$$

$$= \frac{\left[(1+R^*\theta)^{\lambda} - 1\right]}{(1+R^*\theta)^{\lambda}}$$

Hence $$g(R) = \frac{\theta\lambda}{(1+R\theta)^{\lambda+1}} \frac{(1+R^*\theta)^{\lambda}}{\left[(1+R^*\theta)^{\lambda} - 1\right]} \quad ; \quad R < R^*$$

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The moment generating function of random variable R is given by,

$$M_R(t) = E\left(e^{tR}\right)$$

$$= \int_0^{R*} e^{tR} g(R)\ dR$$

$$= \int_0^{R*} e^{tR} \frac{\theta\lambda}{(1+R\theta)^{\lambda+1}} \frac{(1+R*\theta)^{\lambda}}{\left[(1+R*\theta)^{\lambda}-1\right]}\ dR$$

$$= \frac{\theta\lambda(1+R*\theta)^{\lambda}}{\left[(1+R*\theta)^{\lambda}-1\right]} \int_0^{R*} \frac{\left(1+\frac{tR}{1!}+\frac{t^2R^2}{2!}+\cdots\cdots\right)}{(1+R\theta)^{\lambda+1}}\ dR$$

$$\bar{R} = E(R) = \text{Coefficient of } t$$

$$= \frac{1}{\left[(1+R*\theta)^{\lambda}-1\right]}\left[-R*+\frac{(1+R*\theta)\left[(1+R*\theta)^{\lambda-1}-1\right]}{\theta(\lambda-1)}\right]$$

$$E\left(R^2\right) = \text{Coefficient of } \frac{t^2}{2!}$$

$$= \frac{1}{\left[(1+R*\theta)^{\lambda}-1\right]}\left[-R^{*2}-\frac{2R^*\left(1+R^*\theta\right)}{\theta\,(\lambda-1)}+\frac{2\left(1+R^*\theta\right)^2\left[(1+R*\theta)^{\lambda-2}-1\right]}{\theta^2(\lambda-1)(\lambda-2)}\right]$$

Hence from (3.1) we get,

$$I = \frac{\left[-R^{*2}-\frac{2R^*\left(1+R^*\theta\right)}{\theta\,(\lambda-1)}+\frac{2\left(1+R^*\theta\right)^2\left[(1+R*\theta)^{\lambda-2}-1\right]}{\theta^2(\lambda-1)(\lambda-2)}\right]}{R**\left[-R*+\frac{(1+R*\theta)\left[(1+R*\theta)^{\lambda-1}-1\right]}{\theta(\lambda-1)}\right]}$$

4. DATA AND APPLICATION

To illustrate the application of the index, a numerical example with the following data is considered.

% change in Demand D	:	2	1	3	5	1	3	5	1	1	2
% change in Price P	:	5	4	5	9	2	7	7	5	3	7
Price elasticity of demand R	:	0.4	0.25	0.6	0.56	0.5	0.43	0.71	0.2	0.33	0.29

From the above data, we have obtained the estimated value of the parameters θ and λ by using the *method of moments*, which are as follows;

$$\hat{\theta} = 0.4$$

$$\hat{\lambda} = 5.4 \approx 5$$

Let the management specifies the price elasticity of demand R* = 0.5, above which the management and customers are satisfied with the system. And suppose R** = 0.35, which is assumed to be very small price elasticity of demand for the management and P (R <R**) = 0.

Therefore the numerical value of the index comes out to be **I = 0.86**

For the above data set, the numerical value (0.86) of the index indicates that the management and the customers are highly dissatisfied with the system. This may result in loss of business to the management. Therefore, the management needs to take decision for improving the particular inventory system and to maintain the equilibrium between the sale of the products and level of customer's satisfaction.

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