CHAPTER 5

DETERMINING OPTIMAL PROMOTIONAL EXPENSE ALONG WITH PRICE AND LOT-SIZE FOR SOME VEBLEN PRODUCTS WITH DEMAND DEPENDENT ON PRICE AND PROMOTIONAL EXPENSE

5.1 The Problem

Here, the inventory management problem of a single retailer is being considered. The retailer determines the pricing and inventory policies independent of its supplier. The retailer purchases the Veblen product at a unit cost of C_P from the supplier and sells it to its customers at a unit selling price of P.

The following assumptions detail the problem considered here.

(i) There is only one retailer, who purchases goods from a single supplier and optimizes its profit independently of the supplier.

(ii) Replenishment is instantaneous.

(iii) The demand is assumed to be having Veblen effect and dependent on both price as well as advertisement expense.

(iv) Shortages are not allowed.

Irrespective of nature of variation in demand with respect to price, retailer's replenishment cycle will be as shown in Fig. 3.1. The price-sensitive demand follows the relationship as shown in Fig. 3.2 to Fig 3.4. For all the three demand scenario, the demand is assumed to be related to P as $D(P) = -aP^3 + bP^2 - cP + d$.

For the same selling price, different levels of annual demand can be witnessed depending upon the amount of the advertisement expense incurred. In this case, the demand is not only sensitive to the selling price only but also to advertisement expenses. The relation between demand and advertisement budget is taken as, $D(B) = \eta B^{\delta}$, and this relation is shown graphically in Fig. 5.1. This form of relationship between demand

and advertisement budget has been taken from the work of Sana (2008) in which demand was considered as a function of both price and advertisement budget. Here, the demand considered is an additive function of both sales price and advertisement budget as, $\{D(P) + D(B)\}$.

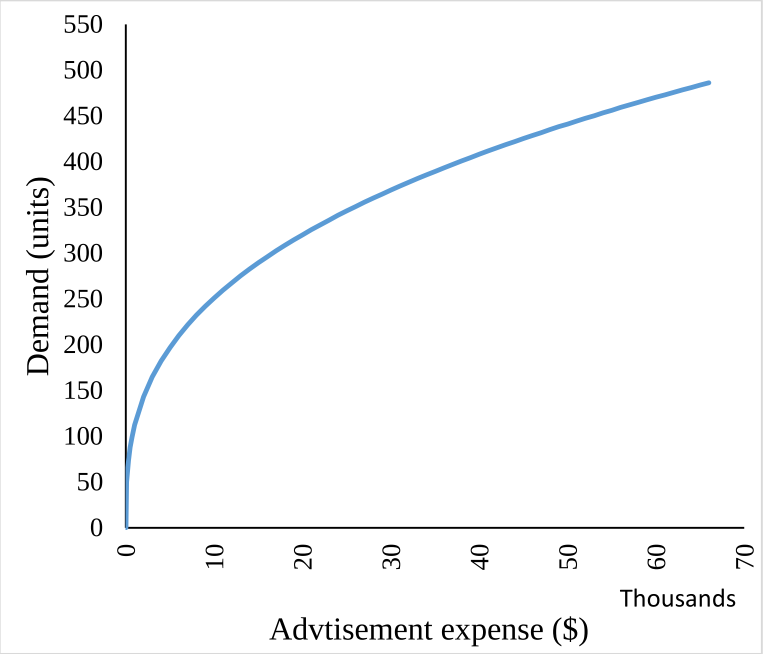

Fig. 5.1 Relationship between demand and advertising expense

Using the problem data, efforts are made to develop an expression for the total profit and is detailed below.

The mathematical expressions are as follows:

Annual Revenue: $R \quad = P\{D(P) + D(B)\}$ (5.1)

Cycle time: $T \quad = \ Q/\{D(P) + D(B)\}$ (5.2)

Annual ordering cost: $O = \ \ A/\mathrm{T}$ (5.3)

Annual purchasing cost: $C = \ C_P\{D(P) + D(B)\}$ (5.4)

Annual holding cost: $H = \frac{h_r C_P \, Q}{2}$ (5.5)

The expression for the profit can be obtained by subtracting various costs from the revenue earned.

$$T_P = \{P\{D(P) + D(B)\} - A/T - C_P\{D(P) + D(B)\} - \frac{h_r C_P Q}{2} - B \quad (5.6)$$

The problem of determining the optimal price, lot-size and promotional expense is expressed in the form of a mathematical model given below that can be used to solve the problem using commercial optimisation software package such as LINGO (Schrage, 2002).

Maximize T_P

subject to

$$T_P = \{P\{D(P) + D(B)\} - A/T - C_P\{D(P) + D(B)\} - \frac{h_r C_P Q}{2} - B$$

$$T = Q/\{D(P) + D(B)\}$$

$$T_P, T, B \geq 0$$

$Q \geq 0$ and integer

The above mathematical model is a non-linear and integer programming problem with discrete solution space, and so it is difficult to solve computationally. Therefore, in order to solve in a computationally efficient manner, heuristics-based approach such as Teaching-Learning-Based Optimisation (TLBO) can be used.

5.2 Effect of Promotional Expense

A numerical problem has been solved to explain the above model. The data has been taken as: $A = 1000$, $C_P = 100$, $h_r = 0.1$, $\eta = 10$, $\delta = 0.35$. The data related to demand scenario is taken from Table 3.1. The optimal results obtained with the help of LINGO software has been shown in Table 5.1. Table 5.2 shows the optimal result without the effect of promotion. Comparing the results obtained in Table 5.1 and Table 5.2, the difference can be clearly seen and this difference is due to the impact of advertisement. The advertisement has influenced the demand and resulted in a gain in revenue and profit. The impact of the advertisement has been shown in Table 5.3 and Fig 5.2. From this table and figure, it can that for the demand scenario I, with the demand increase by 39.46%, the revenue has increased slightly more by 40.74% and profit by 27.57%. The percentage increase in revenue being slightly more than the percentage increase in the demand is due to the slight increase in the selling price by 0.92%. The increase in profit percentage is comparatively low due to the heavy advertisement expense.

Table 5.1 Results obtained with the help of LINGO

Demand scenario	***P*** **($)**	***T*** **(year)**	***B*** **($)**	***D(P)*** **(units)**	***D(B)*** **(units)**	***D(B)+ D(B)*** **(units)**	***Q*** **(units)**	**Revenue ($)**	T_P **($)**
I	240.34	0.46	13467.91	661.01	278.78	939.79	433.54	225867	114085
II	239.79	0.46	13383.51	651.38	278.16	929.54	431.17	222893	112244
III	241.31	0.55	13546.26	379.12	279.34	658.46	362.89	158892	75870

Table 5.2 Results without the effect of advertising

Demand scenario	***P*** **($)**	***T*** **(year)**	***D*** **(units)**	***Q*** **(units)**	**Revenue ($)**	T_P **($)**
I	238.15	0.55	673.89	367.12	160487	89426
II	237.25	0.55	666.20	365.02	158058	87788
III	238.27	0.72	390.72	279.54	93096	51228

Table 5.3 Impact due to advertising

Demand scenario	**Impact due to Advertising in**							
	Selling price		**Demand**		**Revenue**		**Profit**	
	Value	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**
I	2.19	0.92	265.90	39.46	65380	40.74	24658	27.57
II	2.53	1.07	263.35	39.53	64835	41.02	24455	27.86
III	3.04	1.28	267.74	68.53	65796	70.68	24642	48.10

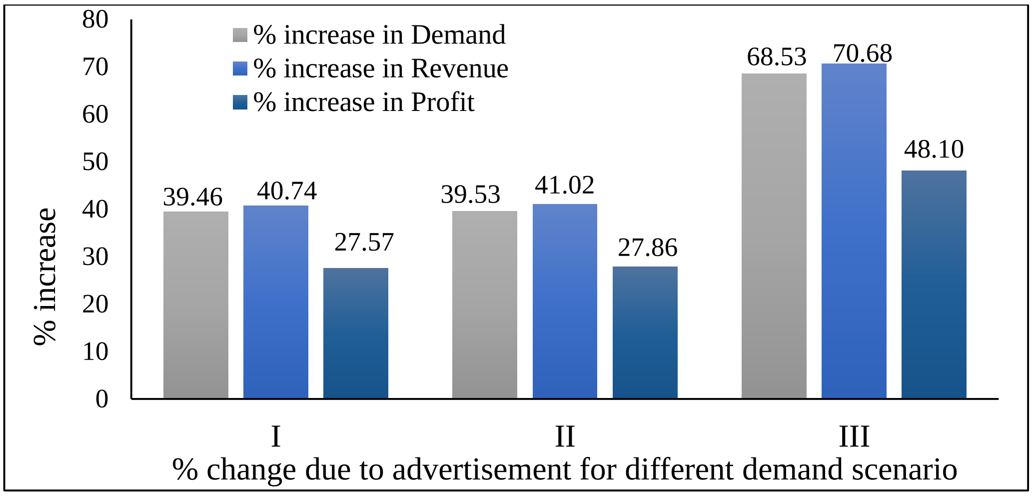

Fig. 5.2 Impact due to the effect of advertising

5.3 Sensitivity analysis

Sensitivity analyses with respect to input parameters h_r, A, and C_P have been carried out to check the robustness of optimal decision with respect to variation in these. For the analyses, the demand curve shown in Fig. 3.2 has been considered. Input parameter values have been varied on either side of their original values.

5.3.1 *Sensitivity analysis with respect to* h_r

The effect of variations in h_r is reported in Table 5.4. From Table 5.4, it is observed that there is a very small change in the optimal sales price with the change in h_r. Since the change in the optimal price is insignificant, the corresponding change in demand will also be insignificant and the same can be observed in Table 5.4. Optimal advertisement expense also changes slightly. With the sales price and the annual demand remaining unaffected, the annual revenue will also remains unaffected. With the revenue being practically constant, the increase in h_r will increase the overall cost and thus the profit margin will come down. This can also be noticed from the results provided in Table 5.4.

From Table 5.4, it can be further noticed that the cycle time decreases with the increase in h_r as it happens in case of classical EOQ model. Since the demand is almost constant and the cycle time is decreasing with the increase in h_r, the optimal order quantity (Q) can be noticed to decrease naturally.

Table 5.4 Sensitivity analysis with respect to h_r

h_r	P	T	B	D(P)	D(B)	D(P)+D(B)	Q	T_P
0.05	240.31	0.6521	13565.15	661.21	279.48	940.69	613	115355
0.06	240.32	0.5953	13542.73	661.17	279.32	940.48	560	115062
0.07	240.32	0.5512	13522.11	661.13	279.17	940.29	518	114793
0.08	240.33	0.5157	13502.94	661.09	279.03	940.12	485	114542
0.09	240.33	0.4862	13484.93	661.05	278.90	939.95	457	114307
0.10	240.34	0.4613	13467.91	661.01	278.78	939.79	434	114085
0.11	240.34	0.4399	13451.72	660.98	278.66	939.64	413	113873
0.12	240.35	0.4212	13436.26	660.95	278.55	939.49	396	113671
0.13	240.35	0.4047	13421.43	660.92	278.44	939.36	380	113477
0.14	240.36	0.3900	13407.17	660.89	278.34	939.22	366	113290
0.15	240.36	0.3768	13393.41	660.86	278.24	939.09	354	113110

5.3.2 *Sensitivity analysis with respect to A*

The results of the sensitivity analysis with respect to the ordering cost (*A*) are shown in Table 5.5. In this case also, the change in the optimal sales price is insignificant with the increase in *A*. Similar to h_r, the change in the demand remains almost unaffected with respect to change in *A*. Similar behaviour was observed in analysing the sensitivity with respect to h_r. The optimal advertisement expense decreases slightly with the change in *A.* With the overall sales price and the annual demand being practically constant, the revenue will also become constant but the profit will come down with the increase in the ordering cost. The same can also be witnessed from Table 5.5.

Optimal values of the cycle time (*T*) and the lot-size quantity (*Q*) both increase with the increase in *A.* This behaviour is also seen in the classical EOQ model where the order-size increases with the increase in the ordering cost. Thus this characteristic is opposite to the observation made while carrying out sensitivity analyses with respect to h_r.

Table 5.5 Sensitivity analysis with respect to A

A	***P***	***T***	***B***	***D(P)***	***D(B)***	***D(P)+D(B)***	***Q***	T_P
500	240.31	0.3260	13565.15	661.21	279.48	940.69	307	115355
600	240.32	0.3572	13542.73	661.17	279.32	940.48	336	115062
700	240.32	0.3859	13522.11	661.13	279.17	940.29	363	114793
800	240.33	0.4125	13502.94	661.09	279.03	940.12	388	114542
900	240.33	0.4376	13484.93	661.05	278.90	939.95	411	114307
1000	240.34	0.4613	13467.91	661.01	278.78	939.79	434	114085
1100	240.34	0.4839	13451.72	660.98	278.66	939.64	455	113873
1200	240.35	0.5054	13436.26	660.95	278.55	939.49	475	113671
1300	240.35	0.5261	13421.43	660.92	278.44	939.36	494	113477
1400	240.36	0.5460	13407.17	660.89	278.34	939.22	513	113290
1500	240.36	0.5652	13393.41	660.86	278.2351	939.09	531	113110

5.3.3 *Sensitivity analysis with respect to C_P*

The outcome of sensitivity analysis with respect to the unit purchasing cost (C_P) is shown in Table 5.6. In the above sensitivity analyses with respect to h_r and A, the change in optimal sales price was observed to be insignificant. But the change is clearly visible with respect to C_P. With the unit cost (C_P) increasing from 50 to 150, the selling price increases from 238.60 to 243.35. The reason for this change is as follows. The increase in C_P will naturally try to push up the sales price. If the selling price is allowed to increase in the same order, the demand will decrease drastically because of the price-demand relationship considered and will cause revenue to shrink. Therefore, the model will not allow such thing to happen and will allow for only a small increase in the sales price while making the best use of the price-demand relationship in order to have the maximum possible profit. This profit can be seen to come down with the fall in revenue because of the increase in the unit purchase cost.

Besides, the change in the demand is also significant with respect to the change in C_P. The reason for this change is as follows. With the increase in C_P, the total cost increases and thus the profit decreases. In order to maximize the profit, the model tries to trade off the demand for the selling price. So, the selling price increases and the demand decreases, and the same is also visible in Table 5.6. The optimal advertisement expense is found to decrease with respect to the increase in the unit purchasing cost. This is in contrast to the insignificant change noticed earlier either with respect to h_r or A. In Table 5.6, the optimal cycle time (T) and order-quantity (Q) both can be observed to decrease with the increase in C_P.

Thus, with the change in C_P, optimal pricing and lot-sizing policies, as well as optimal profit and promotional expenses, are expected to get affected.

Table 5.6 Sensitivity analysis with respect to $\boldsymbol{C_P}$

C_P	*P*	*T*	*B*	*D(P)*	*D(B)*	*D(P)+D(B)*	*Q*	T_P
50	238.60	0.6325	21490.13	671.56	328.31	999.87	632	163924
60	238.89	0.5806	19769.40	670.00	318.86	988.86	574	153679
70	239.20	0.5407	18105.68	668.22	309.20	977.41	528	143572
80	239.54	0.5089	16499.95	666.17	299.31	965.48	491	133603
90	239.92	0.4829	14953.52	663.79	289.17	952.96	460	123772
100	240.34	0.4613	13467.91	661.01	278.78	939.79	434	114085
110	240.80	0.4432	12044.89	657.74	268.09	925.83	410	104545
120	241.33	0.4277	10686.45	653.85	257.09	910.94	390	95160
130	241.92	0.4146	9394.84	649.17	245.76	894.93	371	85940
140	242.59	0.4035	9394.84	643.49	234.06	877.55	354	76895
150	243.35	0.3941	9394.84	636.50	221.96	858.46	338	68040

5.4 Heuristic Approach

The heuristic approach has also been employed to solve the above problem. Here, the heuristic being proposed uses the framework of a metaheuristic and is detailed below. Teaching–Learning–Based Optimisation algorithm has been developed and coded on MATLAB (Version 17) platform.

The TLBO algorithm has already been discussed in Chapter 4. The steps for applying the algorithm is the same as discussed in Section 4.3.2 with the related flowchart being the same as given in Fig. 4.6. The resulted total profit with the number of iterations in the application of TLBO for three demand scenarios has been shown in Fig. 5.3, Fig. 5.4 and Fig. 5.5, respectively. The results obtained with the help of TLBO algorithm has been shown in Table 5.4. The classroom size and the total number of iterations both were taken as 100. From Table 5.1 and Table 5.7, it can be noticed that TLBO provided the same solutions what were obtained from LINGO. However, the CPU time requirement for TLBO approach is more than the time required by LINGO in resulting in the optimal solution. The comparisons of both the results can be seen in Table 5.8.

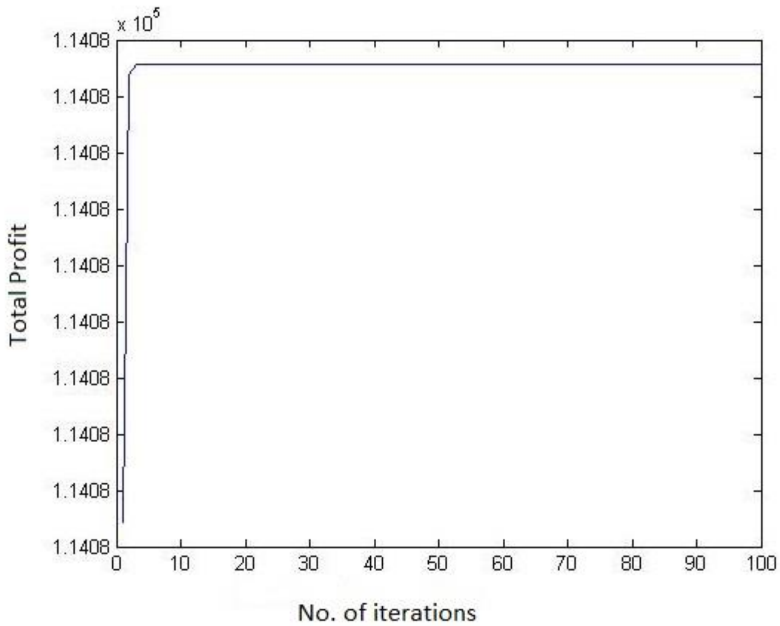

Fig. 5.3 Total profit at different number of iteration of TLBO for demand scenario I

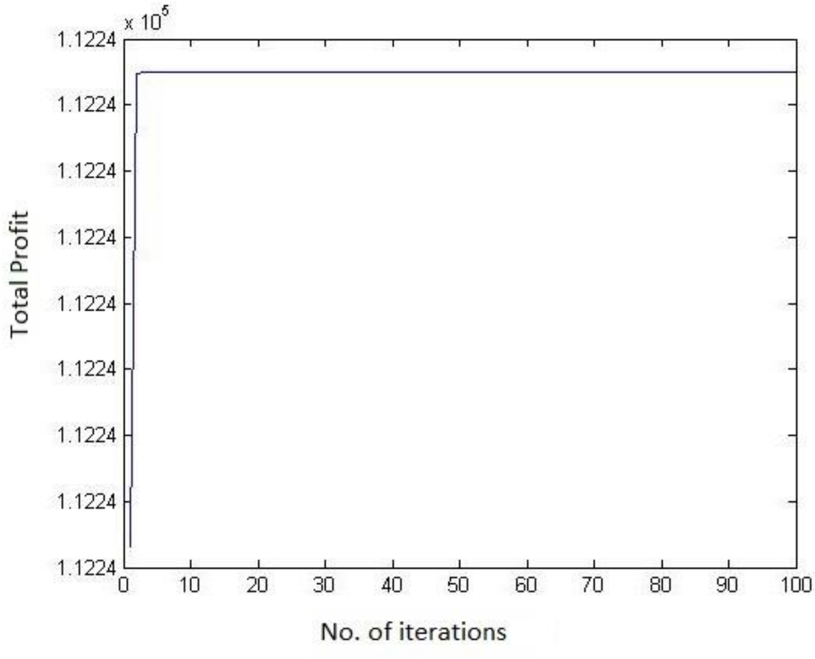

Fig. 5.4 Total profit at different number of iteration of TLBO for demand scenario II

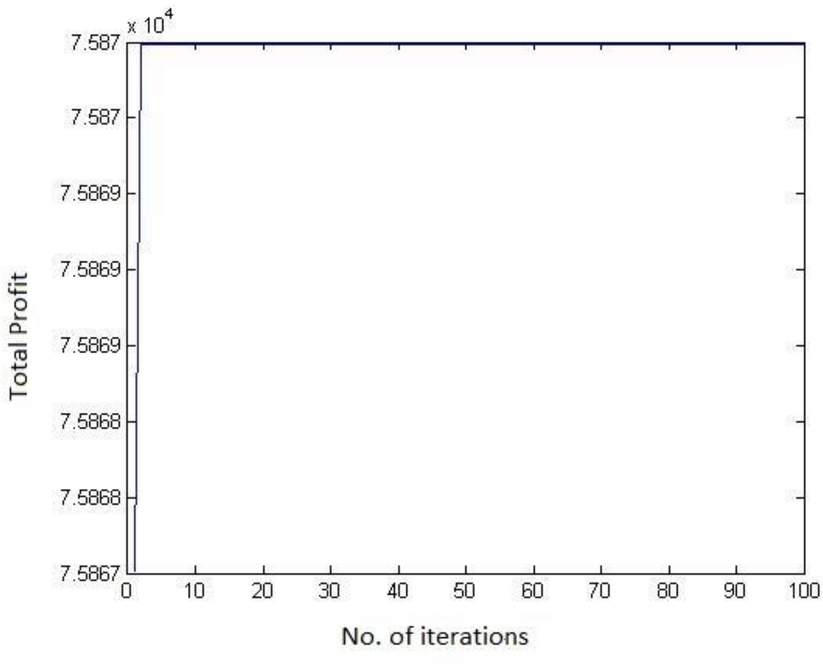

Fig. 5.5 Total profit at different number of iteration of TLBO for demand scenario III

Table 5.7 Results obtained with the help of TLBO algorithm

Demand Scenario	P (\$)	T (year)	B (\$)	T_P (\$)	CPU time for iteration for best result	Iteration
I	240.34	0.4613	13468	114085	0.60	52
II	239.79	0.4639	13384	112243	0.59	49
III	241.31	0.5511	13546	75870	0.69	44

Table 5.8 Comparison of results obtained from LINGO and TLBO

				Demand Scenario		
				I	**II**	**III**
Decision Variable	P	Value (\$)	LINGO (A)	240.34	239.79	241.31
			TLBO (B)	240.34	239.79	241.31
		% Difference	(1-A/B)*100	0.00	0.00	0.00
	T	Value (year)	LINGO (C)	0.4613	0.4639	0.5511
			TLBO (D)	0.4613	0.4639	0.5511
		% Difference	(1-C/D)*100	0.00	0.00	0.00
	B	Value (\$)	LINGO (E)	13467.91	13383.51	13546.26
			TLBO (F)	13467.91	13383.51	13546.26
		% Difference	(1-E/F)*100	0.00	0.00	0.00
Objective Function	T_P	Value (\$)	LINGO (G)	114085	112243	75870
			TLBO (H)	114085	112243	75870
		% Difference	(1-G/H)*100	0.00	0.00	0.00
CPU Time		Value (sec)	LINGO (I)	0.35	0.35	0.33
			TLBO (J)	0.60	0.59	0.68
		% Difference	(1-I/J)*100	41.67	40.67	51.47

5.5 Summary with Managerial Implication

Pricing of a product is an important decision from marketing aspect. It has a great impact on the demand. Maintaining an optimal inventory level, especially in the case of luxury products, is important for the retailer because the related capital investment is high for such products. Advertising and promotion of a luxury product is important in order to increase the brand awareness. Excessive promotion can lead to negative impression on brand, and perception of its luxury value will be reduced. So, it is very important for a marketing manager to have an optimum price, inventory and budget for promotion. In this chapter, an attempt has been made for determining optimal pricing and lot-sizing strategy for the vendor and optimal promotional expense level for marketing people for some Veblen products. It has been observed that the promotional expense has a positive impact on the revenue and profitability. Even though the overall cost increases due to high promotional expenses, but it helps in increasing the demand for the product and finally the overall profitability. The results obtained from the use of TLBO meta-heuristic was found to be equally good but were obtained taking slightly more time. This mathematical model can be used for luxury products in deciding pricing and inventory policies along with the optimal size of the budget for making promotional expenses. With the help of this model, a marketing manager can decide on the optimal amount of fund to be used for product promotion. Retails, on the other hand, can decide the optimal sales price and lot-size for the luxury product.