DECISION SUPPORT FOR PRICE MARKDOWN OF FASHION ITEMS JOHN WALKER

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ABSTRACT

Retailers of fashion items often face the problem of selling a fixed inventory over a short selling season. For a small retailer, with sunk investment in inventory, a major objective is revenue maximization. This paper is concerned with the provision of decision support for the tactical problem of dynamically marking down the price of fashion items in order to increase revenue. A heuristic procedure is developed for quickly identifying, and highlighting for review, fashion items, which are "slow selling" and "economically viable for price markdown". It is shown how a retailer can use such information in determining the timing and magnitude of price markdowns.

INTRODUCTION

Over the past three decades, an increasing number of fashion items have been sold on sale and at higher percentage price markdowns. Research on price markdown policies for fashion items has been undertaken by economists and operational researchers from a range of perspectives.

(Pashigan, 1988) and (Pashigan and Bowen, 1991) provide empirical evidence of the increasing use of price markdown policies (and also increasing initial percentage markups on the unit costs). One of the important reasons noted for these increases is the growing importance of styling and color. In an environment of increasing style and color diversity, a retailer faces corresponding increasing possibilities of pricing and demand forecast errors. Increasing use of price markdown policies is the result of this increasingly uncertain environment. (Wolfe, 1968) and (Feng and Gallego, 1995) consider the optimal timing of a single price change from a given initial unit price to a given lower second unit price. Both papers assume *known demand rates specific to the prices, prior to the start of the selling season*. The assumption is that these demand rates may be estimated by analogy to the sales history of similar fashion items sold in previous seasons. However, as noted above, demand forecasts prior to the start of the season include considerable uncertainty stemming in part from the nature of fashion items having a high degree of style and color content. It would seem, from the empirical evidence given by (Pashigan, 1988) and (Pashigan and Bowen,1991), that increasingly retailers are finding it difficult to determine the correct balance between the specification of the initial unit price, the associated demand forecast prior to the start of the season and subsequent sales. Consequently, in this paper a decision support system is developed for systematically and pragmatically reviewing the timing and magnitude of price markdowns over the season. A heuristic procedure is developed for quickly identifying, and highlighting for review, fashion items, that are "slow selling" and

"economically viable for price markdown". It is shown how a retailer can use such information in determining the timing and magnitude of price markdowns.

THE FASHION ITEM INVENTORY PROBLEM

The essential characteristics of the fashion item inventory problem considered in this paper are as follows.

A Short Selling Season

There is a relatively short selling season (8 to 12 weeks) usually with a well-defined beginning and end, e.g., spring, summer, autumn, winter seasons, particular sports seasons, etc. The end of the season, for a given class of fashion item, may be defined by a retailer as the point beyond which any units that are left in inventory will be considered obsolete and consequently have little disposal value.

A Single Purchase Order

There is a relatively long ordering lead-time (3 to 9 months). With the short selling season and long ordering lead-time, retailers, for all practical purposes, have to commit themselves to a single order to purchase or produce, prior to the start of the season. For example, (Gallego and van Ryzin,1994) describe a major New York fashion producer-retailer that designs, produces (via subcontractors) and sells fashion apparel through its own line of retail outlets.

The process of designing, production and delivery of the garments to the individual retail outlets takes from six to eight months to complete, yet the firm plans to "sell-through" the garments in as little as nine weeks. Similarly, in the case of retailers purchasing direct from trade vendors, the buyers normally review items presented by, and subsequently place orders with, the vendors at trade fashion shows. The trade fashion shows are normally held six to nine months prior to the start of the selling season.

Pre-Season Demand Uncertainty

Demand forecasts for fashion items have to be made many months prior to the start of the selling season. The choice of items involves a great deal of judgement, intuition and "feel for the market". The forecast of the demand for a chosen item is determined in part by analogy to the sales history of similar fashion items sold in previous seasons. Clearly, demand forecasts made prior to the start of the season include considerable uncertainty stemming from the nature of fashion items having a high degree of style and color content and compounded by the long period of inactivity (no sales) between the seasons and ordering lead-time. During these inactive periods, the economic conditions or style considerations may change considerably.

Subsequent High Demand

When the total demand in the season is greater than the inventory made available, sales are foregone and profits lost. With the short selling season and long ordering lead-time, retailers, for all practical purposes, have no re-supply option during the season. Also, once a price is quoted at the start of the season, retailers are normally reluctant to increase the price for fear of losing goodwill. As a result, initial unit prices are set with considerable markups, one reason being to achieve substantial revenues if the demand rates are greater than or equal to the forecasts. A second reason, of being able to allow for subsequent price markdowns, is discussed below.

Subsequent Low Demand

When the total demand in the season is less than the inventory made available, surplus inventory results. There are stocking costs in carrying surplus inventory over to the next appropriate season and, of course, there is no guarantee that such inventory, which may be obsolete, will sell in the new season. Therefore, the surplus inventory is normally disposed of at the end of the current season. However, the unit disposal values of surplus inventory at the end of the season is likely to be far below the unit costs and in many cases are considered to be zero. With the high initial markups noted above, retailers have the opportunity of marking down the unit prices during the season in the expectation of increasing demand. The timing of the price markdowns will depend on the amounts sold to-date and the expected sales over the remaining weeks of the season. Since the season is short it is essential for retailers to identify slow selling items and make decisions on price markdowns as quickly as possible, usually within the first three weeks of the season.

Revenue Maximization

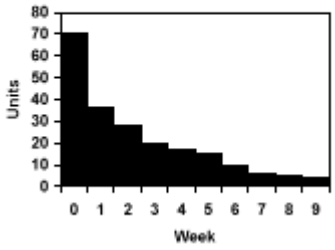
It is clear from the above discussion that after the initial receipt and display of an item, the purchase decision represents a sunk investment in inventory, and a retailer's main objective is revenue maximization. The major difficulty in considering an optimal price markdown policy for revenue maximization is the need for *accurate demand forecasts for different price levels prior to the start of the season*. It would seem, from the empirical evidence of (Pashigan, 1988) and (Pashigan and Bowen, 1991) that increasingly retailers are finding it difficult to determine the correct balance between the specification of the initial unit price, the associated demand forecasts prior to the start of the season and subsequent sales. Accordingly, in this paper, a heuristic procedure is developed for quickly making price markdown decisions. The heuristic is based upon actual inventory levels for the current unit price and has the limited objective of increasing revenue over the remaining weeks of the season above what would have been expected without a price markdown.

Empirical Analysis of Fashion Item Sales

(Wolfe, 1968) conducted an empirical analysis of fashion item sales in women's dress and sportswear departments. Figure 1 illustrates a typical "exponential" inventory level history of an item. (Wolfe, 1968) states that this type of exponential inventory level appears to fit most of the sales histories of fashion items. See also (Lilien, Kotler and

Moorthy,1992, pp. 464 -466).

Figure 1. Weekly Inventory Level



A HEURISTIC PROCEDURE FOR PRICE MARKDOWN

In outline the procedure may be stated in the following manner.

AT THE END OF EACH WEEK
IF (the item is identified as *slow selling*) THEN
IF (the item is identified as *economically viable for price markdown*) THEN
highlight the item for *review* of price markdown
ELSE
highlight the item for *review* of other possibilities
END IF
END IF

In order to make the procedure operational, it is necessary to introduce some notation, the inventory forecast model and to define the terms "*slow selling*", "*economically viable for price markdown*" and "*review*".

Notation and Inventory Forecast Model

n	=	The number of weeks in the selling season.
I_0	=	The initial inventory at the beginning of week 1.
j	=	The index of the week prior to the last price markdown, ($j = 0$ if no prior price markdown).
I_j	=	The inventory at the end of week j.
k	=	The index of the current week.
P_c	=	The current unit price.
F_c	=	The current inventory proportionality factor, $0 < F_c < 1$, associated with P_c.

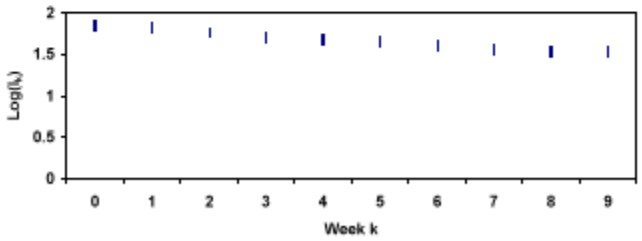
$$I_k = F_c^{k-j} I_j. \quad (1)$$

$$F_c = (I_k/I_j)^{1/(k-j)}. \quad (2)$$

$i(k,I_k,F,t)$ = The forecast for the inventory level at the end of week t given an inventory I_k at the end of week k and an inventory proportionality factor F.

$$i(k,I_k,F,t) = F^{t-k} I_k. \quad (3)$$

Figure 2. Inventory Proportionality Factor



The proposed heuristic procedure is based on the inventory forecast model given by Eq. 3. Eq. 1 provides a simple means of checking the assumption of a constant inventory proportionality factor F. Taking logs, a plot of log(Ik) against k-j should indicate a series of points with a near constant slope of log(Fc). Such a plot for the data of Figure 1 where j = 0 is illustrated in Figure 2. The assumption of a constant inventory proportionality factor appears to be reasonable.

Dynamic Definition of Slow Selling

The dynamic definition of a slow selling item is one such that at the end of week k, with inventory Ik and inventory proportionality factor Fc, the forecast for the inventory level at the end of the season is greater than a retailer desired upper bound for ending inventory, i*kn. A retailer's choice of i*kn will depend partly upon the sales history of similar fashion items sold in previous seasons. Also in the current season upon considerations of the cumulative profit contributions of units sold by the end of week k and required budgeted contribution to profits for the season. Thus, if at the end of week k: i(k,Ik,Fc,n) > i*kn
then the item is defined as a slow selling item and, therefore, highlighted for review.

Dynamic Definition of Economically Viable for Price Markdown

The dynamic definition of an item that is economically viable for price markdown is one such that at the end of week k, the forecast of revenue over the remaining n-k weeks of the season, given a unit price markdown, is greater than or equal to that given by the current unit price. In considering the price markdown, the unit disposal value for surplus inventory at the end of the season is considered to be negligible. The effect of the unit price markdown from Pc to Pm is to change (hopefully decrease!) the current inventory proportionality factor from Fc to some implicit, but unknown, Fm.
Let r(k,Ik,P,F,t) denote the forecast for revenue over weeks k+1, ..., t given an inventory Ik at the end of week k, a unit price P and an inventory proportionality factor F.

$$r(k,I_k,P,F,t) = P[I_k - i(k,I_k,F,t)]. \quad (4)$$

In order for an item to be defined as being economically viable for price markdown:

$$r(k,I_k,P_m,F_m,n) \geq r(k,I_k,P_c,F_c,n).$$

Using Eq. 4: $P_m[I_k - i(k,I_k,F_m,n)] \geq P_c[I_k - i(k,I_k,F_c,n)].$

Using Eq. 3: $P_m[I_k - F_m^{n-k}I_k] \geq P_c[I_k - F_c^{n-k}I_k].$

$$1 - F_m^{n-k} \geq (1 - F_c^{n-k})/(P_m/P_c).$$

Note that if $P_m/P_c \leq 1\text{-}F_c^{n-k}$, a "break-even" inventory proportionality factor for the given fractional markdown P_m/P_c does not exist. Assuming that $P_m/P_c > 1\text{-}F_c^{n-k}$ then:

$$F_m \leq \left[1 - \frac{1 - F_c^{n-k}}{P_m/P_c}\right]^{1/(n-k)}.$$

$$\frac{1 - F_m}{1 - F_c} \geq \frac{1 - \left[1 - \frac{1 - F_c^{n-k}}{P_m/P_c}\right]^{1/(n-k)}}{1 - F_c}. \quad (5)$$

Let $\rho(k,I_k,F_m,F_c)$ denote the ratio of the forecast of sales (sales with a price markdown/sales without a price markdown) for the forthcoming week k+1.

Using Eq. 3: $$\rho(k,I_k,F_m,F_c) = \frac{I_k - F_m I_k}{I_k - F_c I_k} = \frac{1 - F_m}{1 - F_c}. \quad (6)$$

Let $\sigma(n,k,F_c,P_m/P_c)$ denote a lower bound on $\rho(k,I_k,F_m,F_c)$ necessary for

$$r(k,I_k,P_m,F_m,n) \geq r(k,I_k,P_c,F_c,n).$$

From Eq. 5: $$\sigma(n,k,F_c,P_m/P_c) = \frac{1 - \left[1 - \frac{1 - F_c^{n-k}}{P_m/P_c}\right]^{1/(n-k)}}{1 - F_c}.$$

Eq. 5 can now be rewritten:

$$\rho(k,I_k,F_m,F_c) \geq \sigma(n,k,F_c,P_m/P_c). \quad (7)$$

A retailer's judgement and "feel for the current market" can now be utilized in the following manner.

"For a proposed price markdown from Pc to Pm, do you believe sales next week with the price markdown would be at least **s**(n,k,Fc,Pm/Pc) times greater than that without the price markdown".

If so, then the item is defined as being economically viable for a price markdown and,

therefore, highlighted for review.

Note that the inventory proportionality factor Fc can be estimated from Eq. 2 and if an estimate of Fm could be provided then the identification of an economically viable item could be carried out using Eq. 6 and Eq. 7. If records are kept of the details of price markdowns of similar items in previous seasons it may be possible to build regression relationships to predict the inventory proportionality factor. Such predictions could be used to support a retailer in the estimate of the sales ratio for the new fashion item in the current season.

Review Of Markdown And Other Possibilities

The heuristic procedure outlined above allows the quick identification of items that are slow selling and economically viable for a price markdown. However, there are circumstances when a retailer may decide not to implement a price markdown. For example, if a slow mover is identified sufficiently early in the season it may be possible to exchange or return the item to the vendor. Also, the procedure allows for the sequential price markdown of slow selling items. That is, when increased sales achieved by earlier price markdowns are not sufficient to remove the slow mover status in later weeks. Yet, a retailer may prefer a more stable policy of two price markdowns, one mid-season and one end of season clearance sale. The use of the lower bound sales ratio could be used to assess the viability of the proposed price markdown at the mid-season sale.

The heuristic procedure outlined above also allows the quick identification of items that are slow selling but not economically viable for price markdown. Again it may be possible, if the item is identified sufficiently early in the season, to exchange or return the item to the vendor.

If a return or exchange is not possible a retailer may consider other possibilities, e.g., do nothing until the end of the season; announce an immediate clearance sale with substantial price markdown, promotional advertising, increased display; etc.

In both cases, the use of the procedure in quickly identifying slow sellers provides the basis for rationalizing review decisions.

NO PRIOR PRICE MARKDOWN

In this section specialized results are given for case where there has been no prior price markdown, i.e. j = 0.

Definition of Slow Selling

In this case the definition of a slow selling item is redefined. Let f(k,Ik,Fc,I0,n) denote the forecast for the inventory level (expressed as a fraction of initial inventory I0) at the end of week n, given an inventory level Ik at the end of week k and an inventory proportionality factor Fc. A slow selling item is one such that at the end of week k, with

fractional inventory Ik/I0,the forecast for the fractional inventory at the end of the season is greater than a retailer desired upper bound for ending inventory, f*n. Thus:

For a slow seller: $f(k,I_k,F_c,I_0,n) > f^*_n$

Using Eq. 3: $F_c^{n-k}(I_k/I_0) > f^*_n$

Using Eq. 2: $(I_k/I_0)^{(n-k)/k}(I_k/I_0) > f^*_n$

$(I_k/I_0)^{n/k} > f^*_n$

$I_k/I_0 > f^{*\,k/n}_n$.

Let $\gamma(k,n,f^*_n) = f^{*\,k/n}_n$ denote a lower bound on the fractional inventory at the end of the week k necessary for an item to be classified as a slow seller. Thus, if at the end of week k:

$$I_k/I_0 > \gamma(k,n,f^*_n)$$

then the item is defined as a slow selling item and, therefore, highlighted for review.

Table 1 tabulates $\gamma(k,n,f^*_n)$ for n = 12, a range of values of f^*_{12} and k = 1, 2 and 3.

Table 1. Lower Bounds on I_k/I_0 for Slow Sellers

k	f^*_{12}								
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
1	0.83	0.87	0.90	0.93	0.94	0.96	0.97	0.98	0.99
2	0.68	0.76	0.82	0.86	0.89	0.92	0.94	0.96	0.98
3	0.56	0.67	0.74	0.80	0.84	0.88	0.91	0.95	0.97

Example 1 A retailer defines a slow seller such that f*12 = 0.30. Then any item with fractional inventory greater than or equal to 0.90, 0.82 and 0.74 at the end of weeks 11, 2 and 3 respectively is identified as a slow seller.

Definition of Economically Viable for Price Markdown

From Eq. 7 and using Eq.2:

$$\sigma(n,k,F_c,P_m/P_c) = \frac{1-\left[1-\dfrac{1-(I_k/I_0)^{(n-k)/k}}{P_m/P_c}\right]^{1/(n-k)}}{1-(I_k/I_0)^{1/k}}.$$

Table 2 tabulates **s**(12,k,Fc,Pm/Pc) for a range of values of Ik/I0, k = 1, 2, 3 and fractional price markdown Pm/Pc = 0.90, 0.75, 0.50. The range of Ik/I0 covers the lower bound fractional inventory indicated in Table 1 for defining slow selling items within the first three weeks of the season. Similar tables could be constructed to allow considerations of price markdown viability at the end of weeks 4, 5, ..., 11 as the season progresses.

Example 2 Consider the slow selling items identified in Example 1.

For a fractional inventory of 0.90 at the end of week 1 there is no break-even sales ratio in week 2 for a price reduction of 50%. For a 25% (10%) price reduction a break-even sales ratio of 2.01 (1.22) is required in week 2.

For a fractional inventory of 0.82 at the end of week 2 there is no break-even sales ratio

in week 2 for a price reduction of 50%. For a 25% (10%) price reduction a break-even sales ratio of 1.77 (1.20) is required in week 3.

For a fractional inventory of 0.74 at the end of week 3 there is no break-even sales ratio in week 2 for a price reduction of 50%. For a 25% (10%) price reduction a break-even sales ratio of 1.68 (1.19) is required in week 4.

CONCLUSIONS

A heuristic procedure has been developed for supporting retailers in dynamically marking down the price of fashion items in order to increase revenue. The procedure quickly identifies, and highlights for review, items that are slow selling and economically viable for a price markdown. The incorporation of the procedure in a retailer's point-of-sale information system would allow a database and analysis of the inventory proportionality factor ratios of similar items to be maintained. Computer prediction of the inventory proportionality factor ratio could support a retailer's "feel for the current market" in estimating the current sales forecast ratio for determining the economic viability of a price markdown.

Table 2. Lower Bound on Sales Ratio for Forthcoming Week k+1*

	k								
	1			2			3		
	P_m/P_c			P_m/P_c			P_m/P_c		
I_k/I_0	0.50	0.75	0.90	0.50	0.75	0.90	0.50	0.75	0.90
0.70						1.39		1.85	1.21
0.71						1.36		1.80	1.20
0.72						1.34		1.75	1.20
0.73						1.32		1.71	1.19
0.74						1.30		1.68	1.19
0.75						1.28		1.65	1.18
0.76					3.23	1.26		1.62	1.18
0.77					2.46	1.25		1.60	1.17
0.78					2.20	1.24		1.58	1.17
0.79					2.03	1.23		1.56	1.16
0.80					1.92	1.22	4.73	1.54	1.16
0.81					1.84	1.21	3.90	1.52	1.16
0.82			1.78		1.77	1.20	3.49	1.51	1.15
0.83			1.58		1.71	1.19	3.22	1.49	1.15
0.84			1.47		1.66	1.18	3.02	1.48	1.15
0.85			1.40		1.62	1.18	2.87	1.46	1.14
0.86			1.35		1.59	1.17	2.75	1.45	1.14
0.87			1.31		1.56	1.16	2.64	1.44	1.14
0.88			1.27	4.06	1.53	1.16	2.55	1.43	1.14
0.89		2.36	1.25	3.41	1.50	1.15	2.48	1.42	1.13
0.90		2.01	1.22	3.06	1.48	1.15	2.41	1.41	1.13
0.91		1.82	1.21	2.83	1.46	1.14	2.35	1.40	1.13
0.92		1.70	1.19	2.65	1.44	1.14	2.29	1.39	1.13
0.93		1.62	1.18	2.51	1.42	1.13	2.25	1.38	1.12
0.94	5.47	1.55	1.16	2.40	1.41	1.13	2.20	1.37	1.12
0.95	3.30	1.50	1.15	2.31	1.39	1.13	2.16	1.37	1.12
0.96	2.76	1.45	1.14	2.23	1.38	1.12	2.12	1.36	1.12
0.97	2.46	1.42	1.13	2.16	1.37	1.12	2.09	1.35	1.12
0.98	2.26	1.38	1,12	2.10	1.35	1,12	2.06	1.35	1.11
0.99	2.11	1.36	1.12	2.05	1.34	1.11	2.03	1.34	1.11

* A blank entry indicates that no lower bound exists, i.e. no break-even sales ratio

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