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Exploiting a One-Time-Only Sale: An Assessment of the Practicality and Potential Benefits of Alternative Strategies

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Abstract

In exploiting a one-time-only sale by a wholesaler, a retailer may use a special order quantity, or a special retail price, or both. In addition, the retailing firm may leave these decisions to its uncoordinated Procurement and Marketing Departments or develop a coordinated system for their simultaneous determination. The criterion used in these decisions may be the maximization of the average profit (AP) or the maximization of the product's lifetime net present value (NPV). This paper models the behavior of six firms, each using a different approach to the determination of the optimal price and order quantity, and assesses their respective benefits.

The model, which ignores the costs of implementation of the various strategies, shows that the firm that uses a coordinated decision system and the NPV criterion does the best. However, the firm that uses a coordinated system and the AP criterion does almost as well. The paper also finds that when both a special order quantity and a special retail price are employed, the benefits of a coordinated decision system are not significantly greater than the benefits of an uncoordinated system. The benefits of the use of a special retail price are also marginal. Hence, considering the implementation costs of the various strategic elements, the analysis concludes that the most cost-effective strategy for a firm may be to use an uncoordinated system and the AP criterion to determine its optimal special order quantity. Finally, this paper warns that firms that fail to use a special order quantity forego a significant opportunity to improve their average profits and net present values.

INTRODUCTION

A one-time-only sale (OTOS) is a commonly observed practice in industry. Although an OTOS can also occur for perishable and obsolescent products, available OTOS literature has not dealt with such products. Continuing the tradition, this paper deals only with non-perishable products that are deemed to have a continued long-term demand. For such products, an OTOS occurs because a manufacturer/wholesaler wants to reduce some excess inventory caused by such factors as incorrect forecasts or deliberate excess production. Aucamp and Kuzdrall (1986) have also noted that the situation of an announced permanent price increase, with one last opportunity to buy before that price increase, is mathematically equivalent to an OTOS.

A number of authors have modeled a retailer's optimal response to an OTOS of a non-perishable, non-obsolescent product. Assuming standard economic order quantity (EOQ) model conditions, earlier works (Naddor 1966, Brown 1967, Tersine and Grasso 1978, Taylor and Bradley 1985, and Lev and Weiss 1990) developed prescriptive models for determining a special order quantity (Q_s) that a retailer should use in a variety of OTOS situations. Together, these models showed that in OTOS situations with a 10 to 20 percent discount, a retailer's Q_s was likely to be eight to twelve times the normal EOQ, and that the use of such a special order quantity brought substantial savings to the retailer.

Despite the promised savings, Tersine and Grasso (1978) and Hall (1992) observe that the prescribed Q_s are not commonly used. Hall (1992) attempts to explain this phenomenon by suggesting that sales are usually recurring and not one-time-only. Even in true OTOS situations, Tersine and Grasso (1978) suggest that several factors (such as perishability of the material, lack of funds, lack of proper materials-handling equipment, and inadequate warehouse space) impose practical limitations on how large a Q_s the retailer can consider. Usually, the wholesaler also imposes an upper limit on the Q_s by announcing the availability of an OTOS, "only as long as the excess inventory lasts."

On the other hand, if a product is truly non-perishable and non-obsolescent, and if it is only one of the hundreds of items carried by a retailer, Tersine and Grasso's (1978) factors would not explain the lack of use of the traditional OTOS models. Similarly, if a retailer accounts for only a fraction of a wholesaler's total sales of a product, the wholesaler's upper limit may be high enough for a retailer to actually use his optimal Q_s. In addition, a retailer whose Q_s exceeds the wholesaler's maximum allowable quantity would want to order that maximum allowable quantity. Unfortunately, there is no observed evidence of retailers behaving in this manner.

Perhaps the most important reason why, at present, retailers do not seem to exploit OTOS situations may be that practicing procurement managers are not aware of the available decision models or their potential benefits. As the numerical examples in this paper show, if properly exploited, a 20% one-time price reduction could help a retailer improve profits by as much as 40% to 50% of the product's normal profit for a year. It is hoped that this paper will bring that awareness to practicing procurement managers.

While most of the earlier OTOS models relied on the average cost (AC) criterion, Aucamp and Kuzdrall (1986) developed a present value (PV) model and compared its prescriptions and cost implications to those of the AC models. They found that although the recommended Q_s were moderately different for the two criteria, the total costs were essentially the same. In a more recent paper, Hall (1992) also compared a PV model to an AC model for an OTOS situation. Although his numerical results were consistent with Aucamp and Kuzdrall's (1986) results, Hall (1992) emphasized that for 40% or greater OTOS discounts, the AC criterion overestimated the Q_s significantly and increased the costs to the retailer. Based on Hall's (1992) work, it would seem that, since the PV criterion recommends smaller Q_s, its prescriptions might be more practicable. On the other hand, because of its complexity, in most firms, the cost of using a PV model may be significantly greater than the cost of using an AC model.

All of the earlier OTOS works assumed constant demand. Recently, assuming a price-elastic demand, Ardalan (1994 and 1995) suggested that in OTOS situations, in addition to using a $\boldsymbol{Q_s}$, a retailer has the opportunity to increase his demand and profits by charging a special retail price ($\boldsymbol{P_s}$) for that $\boldsymbol{Q_s}$. Clearly, Ardalan's work represents a pioneering contribution to the OTOS theory. Ardalan developed two new models, one maximizing the retailer's net present value (NPV) and another maximizing the growth in the retailer's average profit (AP) in the face of an OTOS with a $\boldsymbol{d\%}$ discount. Ardalan's numerical examples suggested that, compared to the NPV criterion, the AP criterion was substantially suboptimal, and the larger the $\boldsymbol{d}$, the greater the suboptimality. Indeed, one of Ardalan's numerical examples suggested that for $\boldsymbol{d} \geq 65\%$, the use of the AP criterion led to a decline in a firm's NPV, compared to the use of the regular retail price and the EOQ. On the other hand, Ardalan's numerical examples could not confirm Hall's (1992) finding that the $\boldsymbol{Q_s}$ recommended by the NPV criterion was smaller than the $\boldsymbol{Q_s}$ recommended by the AP criterion.

Joglekar and Lee (1997) found that some of Ardalan's (1994 and 1995) conclusions were based on a misformulated AP model, incorrect numerical calculations, and inconsistent comparisons. Although the optimal $\boldsymbol{P_s}$ and $\boldsymbol{Q_s}$ values recommended by a correct AP model were slightly larger than those recommended by the NPV model, the AP model was not as suboptimal as Ardalan claimed. Joglekar and Lee also argued that, in real life, OTOS situations with $\boldsymbol{d} \geq 30\%$ were highly unlikely. On the other hand, Joglekar and Lee (1997) found that despite its technical flaws, Ardalan's (1994) NPV model was sound, and its implementation promised substantial growth in a retailer's NPV. For example, with $\boldsymbol{d} = 20\%$, a retailer's NPV growth ($\boldsymbol{NPV_g}$) could be 7% of the product's normal lifetime NPV. With $\boldsymbol{d} = 30\%$, $\boldsymbol{NPV_g}$ could be as high as 17%.

While these $\boldsymbol{NPV_g}$s are highly attractive, the $\boldsymbol{Q_s}$ values suggested by Ardalan's (1995) numerical examples seem to be phenomenally large. In one example, at $\boldsymbol{d} = 20\%$, $\boldsymbol{Q_s}$ is as large as forty times the retailer's normal EOQ. At $\boldsymbol{d} = 30\%$, $\boldsymbol{Q_s}$ is seventy to ninety times the retailer's normal EOQ, which also amounts to over a one year supply – even at the increased demand rate at the $\boldsymbol{P_s}$. In practice, both the wholesaler and the retailer may find such large values of $\boldsymbol{Q_s}$ unacceptable.

Furthermore, Ardalan's (1994) model overestimates its own benefits insofar as it assumes no additional costs of implementation. Ardalan's model requires several changes in a retailer's normal decision structure and practices, each of which may impose substantial additional costs on the retailer. First, Ardalan's model requires the use of a $\boldsymbol{P_s}$ for the quantity bought at an OTOS. This means the retailer has to incur additional costs to communicate the price change to employees and customers. Second, Ardalan's (1994) model requires that $\boldsymbol{P_s}$ and $\boldsymbol{Q_s}$ values be determined simultaneously. This requires substantial coordination between the marketing and the procurement departments in a firm. Although many marketing and logistics scholars (Drucker 1962, Ledany and Sternlieb 1973, Bartels 1982, Voorhees and Coppett 1986, Christopher 1992) have called for an integration of these two functions, a coordination between the two is non-existent in most companies today. Hence, the design and operation of a coordinated system would entail sizable costs. To use Ardalan's model, a retailer must incur sizable costs to train his marketing and procurement managers in the theory and procedures of NPV calculations.

The additional costs of the various strategic elements in Ardalan's (1994) model are likely to be very different from firm to firm, and rather difficult to estimate. However, because the benefits promised by Ardalan's model are so attractive, these strategy elements deserve careful scrutiny. Hence, the purpose of this paper is to isolate and assess the relative benefits of each strategy element, so that a retailer could target an implementation of the element(s) with the greatest promise.

This paper models the behavior of six firms, each facing an identical OTOS situation, but each following a different combination of the four strategic elements implied by Ardalan's (1994) model, namely: the use of a special order quantity, the use of a special retail price, the use of a coordinated decision system, and the use of the NPV criterion. The model helps assess the growth in each firm's NPV under a given OTOS discount. A numerical example is provided along with a sensitivity analysis.

Among the six firms, the analysis shows that the one that maximizes its NPV using a coordinated decision system does the best (not counting the costs of implementing that strategy). However, in most situations, the use of the AP criterion and the use of an uncoordinated decision system does not lead to high degrees of suboptimality (as long as the firm places a special order). Thus, the good news is that most firms need not modify their current decision systems or criteria. After all, the costs of setting up and operating a coordinated decision system, and those of using the NPV criterion, are likely to be sizable.

The analysis also shows that firms whose procurement departments ignore the one-time-only nature of a sale (i.e. who do not use a special order quantity) forego significant improvements in their profits and NPVs. Consequently, it seems urgent that procurement managers become aware of the classical OTOS models and use them to exploit the opportunities offered by one-time-only sales. The paper ends with a summary of its findings, along with a few cautionary notes and directions for further research.

THE MODEL

Consider six retail firms, A, B, C, D, E, and F. Each firm regularly buys a product from a wholesaler at a price $\boldsymbol{c}$ per unit and sells it at a price of $\boldsymbol{P_r}$ per unit. The product's annual demand, $\boldsymbol{R}$, is price-elastic. Although available literature considers a variety of conditions for the timing of an OTOS, without loss of generality, this paper assumes that the wholesaler has announced an OTOS discount of $\boldsymbol{d\%}$, available at the time of each firm's next order. All firms are rational. The six firms use six different decision processes and criteria. At Firms A, B, C, and D, both the regular and the OTOS decisions are uncoordinated. At Firms E and F, price and order quantity decisions are coordinated, i.e. made simultaneously. Firm F uses the criterion of maximizing the NPV of its lifetime cash flows, whereas the rest of the firms focus on maximizing the AP.

Thus, in the absence of an OTOS, at Firms A to D, the Marketing Department first determines the optimal regular price, $\boldsymbol{P_r}$, so as to maximize π_M, the average annual profit as estimated by the Marketing Department (i.e. excluding the inventory-related costs). Then, the Procurement Department uses the EOQ formula to determine the optimal regular order quantity, $\boldsymbol{Q_r}$. At Firm E, $\boldsymbol{P_r}$ and $\boldsymbol{Q_r}$ are determined simultaneously to maximize π_r, the average annual profit net of inventory related costs. At Firm F, $\boldsymbol{P_r}$ and $\boldsymbol{Q_r}$

are determined simultaneously to maximize the product's NPV from lifetime revenue and cost cash streams (NPV_r).

In response to the OTOS, at Firm A, no changes are made in P_r and Q_r. At Firm B, P_r is left unchanged. However, recognizing the one-time nature of the sale, the Procurement Department determines a special optimal order quantity, Q_s, that maximizes g, the increase in the firm's AP over the AP it would have made by implementing the regular policies during T_s, the time covered by Q_s. At Firm C, recognizing the price-elastic demand, the Marketing Department determines a P_s to maximize π_M at the discounted cost. However, the Procurement Department simply computes a new EOQ to accommodate the changed cost, price, and demand. The Marketing Department at Firm D first determines a P_s. Then (as at Firm B) Firm D's Procurement Department determines the Q_s that maximizes g. At Firm E, P_s and Q_s are determined simultaneously to maximize g. At Firm F, P_s and Q_s are determined simultaneously to maximize the product's NPV accounting for lifetime revenue and cost cash streams including those under the OTOS NPV_s). An implied assumption in the model is that in order to use the NPV criterion a firm must have a coordinated decision system. For a quick reference, Table 1 summarizes each firm's decision processes and criteria.

TABLE 1

A Summary of Each Firm's Decision Processes and Strategies

Firm	**Decision System**	**Criteria for Regular Decisions on:**		**Response to OTOS in:**	
		Pricing	**Order Quantity**	**Pricing**	**Order Quantity**
A	uncoordinated	Max π_m	EOQ	No Change	No Change
B	uncoordinated	Max π_m	EOQ	No Change	Q_s to Max g
C	uncoordinated	Max π_m	EOQ	P_s to Max new π_m	New EOQ
D	uncoordinated	Max π_m	EOQ	P_s to Max new π_m	Q_s to Max g
E	coordinated	Max π_r		P_s and Q_s to Max g	
F	coordinated	Max NPV_r		P_s and Q_s to Max NPV_s	

The following model enables the comparison of the impact of these alternative decision processes and criteria on each firm's decisions and consequences.

Notation

c = Retailer's regular cost per unit (i.e. wholesaler's regular price).

d = Amount of one-time discount offered by the wholesaler. In the model, d is a dollar amount. In the numerical examples, d is expressed as a % of c.

g = The growth in retailer's total profit due to the one-time special order.

H = Inventory storage, handling, record keeping, and other carrying costs that are constant per unit per year regardless of the purchase cost of a unit.
Note that Ardalan (1994) assumes all non-capital inventory costs to be of this type, whereas Ardalan (1995) assumes them to be of h type defined below. This paper's model permits the treatment of either type and even allows for a mixture of the two types.

h = Inventory shrinkage, obsolescence, and other carrying costs (but not the capital cost) that are constant per dollar of inventory per year.

I = Capital cost of inventory investment per dollar per year (also the discount rate used in all NPV calculations).

M_r = The maximum of the six firm's NPV_rs.

M_s = The maximum of the six firm's NPV_ss.

M_g = The maximum of the six firm's NPV_gs.

$\%M_r$ = A firm's NPV_r as a percent of M_r.

$\%M_s$ = A firm's NPV_s as a percent of M_s.

$\%M_g$ = A firm's NPV_g as a percent of M_g.

NPV_r = NPV of a retailer's lifetime cash flows from his regular policies.

NPV_s = NPV of a retailer's lifetime cash flows from special price and order quantity decisions followed by regular policies.

NPV_g = The growth in a retailer's NPV of lifetime cash flows due to the OTOS
$NPV_g = NPV_s - NPV_r$.

P_r = Retailer's regular selling price.

P_s = Retailer's selling price for the special quantity bought on an OTOS.

Q = Retailer's order quantity in general.

Q_r = Retailer's regular order quantity.

Q_s = Retailer's special order quantity in response to the OTOS.

R_r = Demand per year at retailer's regular selling price.

R_s = Demand per year at retailer's special selling price.

T_s = Time duration over which the special order quantity lasts.

S = Retailer's ordering cost per order.

ε = Price elasticity of retailer's demand (i.e. the number of units by which demand increases for each dollar reduction in the retail price).

ϕ = Retailer's average profit from the one-time special order.

π_m = Annual profit as estimated by the retailer's Marketing Department (i.e. excluding inventory-related costs).

π_r = Retailer's regular annual profit net of inventory related costs.

The Regular Policies at Each Firm

Annual demand is assumed to be a monotonically declining function of price

(1) $R_r = f(P_r, \varepsilon)$

In the uncoordinated firms A, B, C, and D, the Marketing Department sets the P_r by maximizing

(2) $\pi_m = (P_r - c)R_r$

Given the optimal P_r^* and the corresponding R_r^*, the Procurement Department decides on the optimal Q_r^* by the EOQ formula

(3) $Q_r^* = \{2R_r^*S/[H + c(h + i)]\}^{1/2}$

Thus, at Firms A, B, C, and D, the regular annual profit is given by

(4) $\pi_r^* = (P_r^* - c)R_r^* - \{(R_r^*S/Q_r^*) + (1/2)Q_r^*[H + c(h + i)]\}$

and the NPV of lifetime cash flows under these regular policies is given by

(5) $$NPV_r^* = P_r^* R_r^* \int_0^{\infty} e^{-it}\,dt - \sum_{n=0}^{\infty} \{S + Q_r^*c + [H + hc] \int_0^{Q_r^*/R_r^*} (Q_r^* - R_r^*t)e^{-it}\,dt\} e^{-ni(Qr^*/Rr^*)}$$

$$= P_r^* R_r^* /i - \{S + Q_r^*c + [H + hc][Q_r^*/i + R_r^*e^{-i(Qr^*/Rr^*)}/i^2 - R_r^*/i^2]\}/(1 - e^{-i(Qr^*/Rr^*)})$$

In contrast, at Firm E, the optimal regular policies are established by maximizing Equation (6) below with respect to P_r and Q_r simultaneously.

(6) $\pi_r = (P_r - c)R_r - \{(R_rS/Q_r) + (1/2)Q_r[H + c(h + i)]\}$

In the past, it was important for an operations researcher to describe precisely how this type of an equation would be maximized with respect to P_r and Q_r simultaneously. However, today several standard software products, such as Microsoft Excel® with its "solver" function, can handle such maximization almost automatically. As such, it is unnecessary to describe the required maximization procedures. Using the P_r^*, Q_r^*, and R_r^* resulting from the maximization of (6) in (4) and (5), one can find Firm E's π_r^* and NPV_r^*.

At Firm F, the optimal regular policies are established by maximizing Equation (7) below with respect to P_r and Q_r simultaneously.

$$(7)\quad NPV_r = P_r R_r \int_0^{\infty} e^{-it}\,dt - \sum_{n=0}^{\infty}[S + Q_r c + [H + hc] \int_0^{Q_r/R_r} (Q_r - R_r t)e^{-it}\,dt]e^{-ni(Qr/Rr)}$$
$$= P_r R_r/i - \{S + Q_r c + [H + hc][Q_r/i + R_r e^{-i(Qr/Rr)}/i^2 - R_r/i^2]\}/(1 - e^{-i(Qr/Rr)})$$

Using the resultant P_r*, Q_r*, and R_r* in (4) and (7), one can find Firm F's π_r* and NPV_r*.

When each of the six firms' NPV_r s are evaluated, the maximum of the six values is recognized as the M_r, and the performance of each of the firms in relation to that M_r is evaluated by calculating $\%M_r$, the firm's NPV_r as a percent of that M_r. In this model, by definition, Firm F maximizes its NPV_r. Hence, M_r is given by Firm F's NPV_r.

Each Firm's Special Policies In An OTOS Situation

In an OTOS situation, if Q_s is the special order quantity and P_s is the special retail price for that quantity, the annual demand rate for that quantity is given by

$$(8)\quad R_s = f(P_s, \varepsilon)$$

Hence, T_s is given by

$$(9)\quad T_s = Q_s/R_s$$

The retailer's average profit from this special inventory cycle is given by

$$(10)\quad \phi = (P_s - c + d)Q_s - \{S + (1/2)Q_s\,[H + (c - d)(h + i)]\,T_s\}$$
$$= (P_s - c + d)Q_s - \{S + (1/2)Q_s^2\,[H + (c - d)(h + i)]/R_s\}$$

However, during the special cycle, the retailer foregoes a regular profit of $T_s\pi_r$*. Thus, g, the growth in the retailer's average profit due to the special order is given by

$$(11)\quad g = \phi - T_s\pi_r^* = (P_s - c + d)Q_s - \{S + (1/2)Q_s^2\,[H + (c - d)(h + i)]/R_s\}$$
$$- (Q_s/R_s)\{(P_r^* - c)R_r^* - [(R_r^* S/Q_r^*) + (1/2)Q_r^*[H + c(h + i)]]\}$$

The NPV of the retailer's lifetime cash flows resulting from the special order, followed by the use of the regular policy for the rest of the life of the product, is given by

$$(12)\quad NPV_s = P_s R_s \int_0^{Q_s/R_s} e^{-it}\,dt + (NPV_r^*)e^{-i(Qs/Rs)}$$
$$- \{S + Q_s(c - d) + [H + (c - d)(h)] \int_0^{Q_s/R_s} (Q_s - R_s t)e^{-it}dt\}$$
$$= P_s R_s(1 - e^{-i(Qs/Rs)})/i + (NPV_r^*)e^{-i(Qs/Rs)}$$
$$- \{S + Q_s(c - d) + [H + (c - d)(h)][Q_s/i + R_s e^{-i(Qs/Rs)}/i^2 - R_s/i^2]\}$$

where, NPV_r^* is given by Equation (5).
Thus, NPV_g, the growth in the retailer's NPV due to the special order is given by

$$(13)\quad NPV_g = NPV_s - NPV_r^* \\ = P_s R_s(1 - e^{-i(Q_s/R_s)})/i - (NPV_r^*)(1 - e^{-i(Q_s/R_s)}) \\ - \{S + Q_s (c - d) + [H + (c - d)(h + i)][Q_s/i + R_s e^{-i(Q_s/R_s)}/i^2 - R_s/i^2]\}$$

In the face of an OTOS, Firm A does not revise its price and order quantity decisions. Hence, for Firm A

$$(14)\quad P_s^* = P_r^*, \quad Q_s^* = Q_r^*, \quad and \quad R_s^* = R_r^*$$

Substituting (14) in (12) to (13) one can obtain Firm A's the NPV_g.

At Firm B, the Marketing Department is not responsive. Hence,

$$(15)\quad P_s = P_r^* \text{ and } R_s = R_r^*$$

Substituting (15) in (10) and (11), Firm B's Procurement Department reformulates its g and maximizes it with respect to Q_s. Using that Q_s^* in (12) and (13) one can calculate B's NPV_g.

At Firm C, the Marketing Department revises its sale price, P_s, to maximize

$$(16)\quad \pi_m = (P_s - c + d)R_s$$

Then, Firm C's Procurement Department recalculates its Q_s by the EOQ formula

$$(17)\quad Q_s^* = \{2R_s^*S/[H + (c- d)(h + i)]\}^{1/2}$$

Using the solutions to (16) and (17) in (12) and (13), one can find Firm C's NPV_g.

At Firm D, the Marketing Department revises its P_s to maximize (16). Then, using that P_s in the reformulation of (11), the Procurement Department maximizes (11) with respect to Q_s. Using these solutions in (12) and (13), one can compute Firm D's NPV_g.

In the face of an OTOS, Firm E chooses its optimal P_s^* and Q_s^* by maximizing Equation (11) simultaneously with respect to P_s and Q_s. Using the resulting optimal values of P_s^*, Q_s^*, and R_s^* in (13), one can obtain Firm E's NPV_g.

Firm F chooses its optimal P_s^* and Q_s^* by maximizing Equation (13) simultaneously with respect to P_s and Q_s. Using the resulting optimal values of P_s^*, Q_s^*, and R_s^* in (13), one can obtain Firm F's NPV_g.

When each of the six firms' NPV_ss are evaluated, the maximum of the six values is recognized as the M_s, and the performance of each of the firms in relation to that M_s is evaluated by calculating $\%M_s$, the firm's NPV_s as a percent of that M_s. In this model, M_s is given by Firm F's NPV_s. Similarly, M_g is given by Firm F's NPV_g and $\%M_g$ helps assess the performance of each firm in relation to that M_g.

The above model is general and can accommodate most real-life situations, including those involving non-linear demand functions. However, this paper presents a single numerical example, with a linear demand function, to illustrate the results and to draw some important conclusions. The numerical example is followed by a sensitivity analysis that enables additional insights and more general conclusions.

A NUMERICAL EXAMPLE

Each Firm's Regular Decisions and Consequences

Table 2 summarizes the numerical assumptions and the regular decisions and consequences for each firm. Although the numbers presented are rounded, the underlying computations are not. As predicated by the model, all the decisions and consequences for firms A to D are identical. Each one of these firms retails the product for $13.33/unit and enjoys an annual demand of 20,000 units. This maximizes the annual profit as calculated by the Marketing Department to $66,667. Each uses an order quantity of 1,069 units/order and enjoys an annual profit (net of inventory costs) of $31,830. The NPV of each firm's lifetime cash flows is $419,433.

TABLE 2
Each Firm's Regular Situation:
Assumptions, Decisions, and Consequences

Assumptions common to all firms

c = $10/unit, ***S = $100/order,*** ***h = 10%/$/year,***
H = $1/unit/year, ***i = 15%/year,*** ε ***= 6000 units/$.***

Each Firm's Regular Decisions

Firm	A	B	C	D	E	F
P_r	$13.33	$13.33	$13.33	$13.33	$13.38	$13.38
Q_r (units/order)	1,069	1,069	1,069	1,069	1,061	1,060

Each Firm's Consequences Due to Regular Decisions

Firm	A	B	C	D	E	F
R_r (units/year)	20,000	20,000	20,000	20,000	19,717	19,717
π_m	$66,667	$66,667	$66,667	$66,667	$66,653	$66,653
π_r	$31,830	$31,830	$31,830	$31,830	$31,831	$31,831
NPV_r ($)	$419,433	$419,433	$419,433	$419,433	$419,521	$419,521
$\%M_r$	99.98	99.98	99.98	99.98	100.00	100.00

The decisions and consequences for firms E and F are slightly different from those for firms A to D, but practically identical with each other. Each of these firms retails the product at a slightly higher price of $13.38/unit, and experiences a slightly lower demand of 19,717 units per year. Firms E and F also order slightly smaller $\boldsymbol{Q_r}$. Consequently, their annual profits as calculated by the Marketing Departments are slightly smaller (if only by $14) than those for Firms A to D. However, net of inventory costs, their annual profits are slightly larger (if only by a dollar) than those for Firms A to D. Firms E and F both enjoy slightly higher $\boldsymbol{NPV_r}$ values ($419,521) than those enjoyed by firm A to D ($419,433). The $\boldsymbol{\%M_r}$s in the last row of Table 2 are given by each firm's $\boldsymbol{NPV_r}$ as a percent of Firm F's $\boldsymbol{NPV_r}$. The fact that Firms E and F have almost identical $\boldsymbol{NPV_r}$ confirms Hadley's (1964) long-standing assertion that under classical EOQ assumptions the use of the AP criterion leads to consequences that are practically identical to those of using the NPV criterion.

The differences between the results of the coordinated firms E and F and those of the uncoordinated firms A to D are relatively more important than the differences caused by the use of the NPV or the AP criterion. However, based on the $\boldsymbol{\%M_r}$s in Table 2, compared to the coordinated firms, the uncoordinated firms compromise only 1/50th of 1% of a product's lifetime NPV. These differences can also be seen as practically insignificant. Thus, under EOQ assumptions, it is not important that the decisions in a firm's Marketing and Procurement Departments be coordinated. To the extent that this finding is not commonly known, it represents an important contribution of this paper.

Each Firm's Special Decisions and Consequences in the Face of An OTOS

Assuming an OTOS discount of 20%, Table 3 summarizes each firm's optimal $\boldsymbol{P_s}$ and $\boldsymbol{Q_s}$ values, as well as the resultant consequences, in terms of $\boldsymbol{R_s}$, $\boldsymbol{g}$, $\boldsymbol{NPV_s}$, $\boldsymbol{NPV_g}$, $\boldsymbol{\%M_s}$, and $\boldsymbol{\%M_g}$. Observe that the decisions and the consequences are substantially different from firm to firm. As expected, Firm F, which seeks to maximize its NPV, attains the greatest value of $\boldsymbol{NPV_s}$ ($435,190).

Recall that Firm A is not responsive to the OTOS. It simply continues to use its regular price of $13.33/unit and its regular order quantity of 1,069 units/order. Hence, it only obtains the windfall of a 20% reduction in the price of its next order of 1,069 units. Consequently, Firm A's, $\boldsymbol{g}$, the AP growth due to the OTOS, is $2,152. This compares rather poorly with the $\boldsymbol{g}$ the other firms attain. For example, Firm E's $\boldsymbol{g}$ is as large as $16,758. Firm A's $\boldsymbol{\%M_s}$ (96.87%) does not look too bad. However, remember that $\boldsymbol{\%M_s}$ is related to the NPV of lifetime cash flows of the product. $\boldsymbol{\%M_g}$ shows that Firm A attains only 13.68% of the NPV growth that Firm F attains. In short, Firm A's results show that when a firm refuses to exploit an OTOS, it foregoes a significant growth in its profits, whether measured on an AP or on an NPV basis.

TABLE 3
Each Firm's Special Decisions and Consequences for d = 20%

Each Firm's Special Decisions						
Firm	**A**	**B**	**C**	**D**	**E**	**F**
P_s **($/unit)**	13.33	13.33	12.33	12.33	12.86	12.84
Q_s **(units/order)**	1,069	14,581	1,317	16,581	16,023	15,276
Each Firm's Consequences						
Firm	**A**	**B**	**C**	**D**	**E**	**F**
R_s **(units/year)**	20,000	20,000	26,000	26,000	22,844	22,956
g **($)**	2,152	15,844	2,319	15,760	16,758	16,716
NPV_s **($)**	421,577	434,169	421,743	434,224	435,149	435,190
$\%M_s$	96.87	99.77	96.91	99.78	99.99	100.00
NPV_g **($)**	2,144	14,735	2,310	14,790	15,627	15,669
$\%M_g$	13.68	94.04	14.74	94.39	99.73	100.00

In comparison, Firm B, which ignores the price elasticity of demand and continues to retail the product at $13.33/unit, but uses a Q_s of 14,581 units that maximizes its g, does very well. Its g ($15,844) is 50% of the product's normal annual profit ($31,830) and 95% of the largest possible g ($16,758 for Firm E). Firm B's NPV_s ($434,169) is 99.97% of the largest NPV_s ($435,190 for Firm F), and its $\%M_g$ is 94.04%. Furthermore, in implementing its optimal decisions, unlike some other firms, Firm B need not incur the costs of communicating a price change, or costs of setting up a coordinated system, or the costs of training in NPV concepts. Thus, Firm B's strategy seems to be cost-efficient. Although B's Q_s is almost fourteen times the normal EOQ, it is equivalent to only nine months' supply, and need not be ruled out as infeasible. Even if there is an upper limit on the Q_s acceptable to the wholesaler, B should use that upper limit as its Q_s to exploit the benefit offered by the OTOS. To the extent that this conclusion is not generally known, it represents another major contribution of this paper.

Firm C's Marketing Department recognizes the price sensitivity of demand and uses a P_s of $12.33/unit increasing its demand rate for that quantity to 26,000 units/year. However, ignoring the one-time-only nature of the sale, Firm C's Procurement Department simply uses the EOQ formula to calculate a Q_s of 1,317 units. The AP and NPV consequences in Table 3 show that Firm C does only marginally better than Firm A, and substantially worse than the rest of the firms. Thus, responding only to the price sensitivity of demand but not to the one-time-only nature of the sale may be almost as bad as not responding at all. Indeed, it may be worse, insofar as the costs of communicating the new P_s may be greater than Firm C's marginal advantage over Firm A.

Like Firms A to C, Firm D also has an uncoordinated decision system. However, at D, both the Marketing and the Procurement Departments are vigilant about an OTOS. Like Firm C, Firm D uses a P_s of \$12.33/unit to increase its demand rate for that quantity. Then recognizing the new demand rate and the one-time-only nature of the sale, Firm D's Procurement Department develops a Q_s of 16,581 units that maximizes its g. Firm D's consequences are considerably better than those of Firms A and C. Thus, responding to the one-time nature of the sale seems to help considerably.

On the other hand, Firm D's g is actually smaller than B's g, and its NPV_s and NPV_g are only marginally better than B's. It follows that in OTOS situations, responding to demand elasticity is not very helpful. This is particularly true if Firm D's costs of communicating the new P_s are greater than D's marginal advantage over B.

Unlike Firms A to D, Firm E uses a coordinated decision system to simultaneously determine the P_s and Q_s that maximize g. Although Firm E's g (\$16,758) is the largest of all gs in Table 3, it is only 6% larger than Firm B's g. Its NPV_g is also only 6% higher than Firm B's NPV_g. Considering that Firm E must incur additional costs of communicating the price change and setting up a coordinated system, these increases may not be worthwhile.

Firm F also uses a coordinated system and the NPV criterion to determine its optimal P_s and Q_s. Consequently, Firm F attains the greatest values of NPV_s and NPV_g among the six firms. Although F's P_s and Q_s are different from E's, they are not as dramatically different as in Ardalan's numerical examples. Thus, this analysis confirms Joglekar and Lee's (1997) findings about the inaccuracies in Ardalan's (1995) work.

More importantly, Table 3 shows that, in terms of NPV_g, Firm E does almost as well as Firm F. Thus, contrary to Ardalan's (1995) suggestion, one can conclude that in OTOS situations, the use of the AP criterion does not seriously compromise a firm's growth in NPV. Indeed, insofar as the use of the NPV criterion entails additional costs of training one's managers in the NPV concepts and procedures, a retailer may prefer the use of the AP criterion.

In short, it seems that among the six firms, Firm B's approach may be the most cost-effective one. Firm B uses an uncoordinated decision system, ignores the price elasticity of demand, and responds to the one-time-only nature of an OTOS by ordering a special order quantity to maximize its per-period profit. In other words, Firm B could use any of the classical OTOS models (Naddor 1966, Brown 1967, Tersine and Grasso 1978, Taylor and Bradley 1985, or Lev and Weiss 1990) rather than using the more recent but complicated models such as Ardalan (1994 and 1995).

SENSITIVITY ANALYSIS

To ensure that the foregoing conclusions are not subject to the specific numerical values assumed, a comprehensive sensitivity analysis was undertaken. Table 4 presents one example of the sensitivity analysis. It reports the effects of a downward and an upward change in each major parameter of the model on the resultant NPV_g and $\%M_g$ for each firm. The base case assumptions are identical to those in Table 3 and are reiterated at the bottom of Table 4. The left-most column of Table 4 indicates the parameter value that is changed, with the rest of the parameters remaining unchanged from the base case. The first row in Table 4 (with none of the factors changed) provides the base case NPV_g and $\%M_g$ values for each firm. The rest of the rows are to be compared with this base case and with one another.

Regardless of what parameter is changed, Firm F's NPV_g is always the greatest. This confirms that a firm using a coordinated system with the NPV criterion always does the best. Firm E's NPV_g is always the second highest. Thus, a firm using a coordinated system but the AP criterion does better than the remaining firms. Furthermore, Firm E's $\%M_g$s range between 99.37% to 99.93%, confirming that (in most OTOS situations) the AP criterion's results are practically the same as those of the NPV criterion.

Table 4 also shows that Firm A always does the worst among all firms. Firm A's $\%M_g$s range between 8.83% to 25.68%. This suggests that a firm risks forfeiting a significant opportunity for improving its NPV if it does not seek to actively exploit an OTOS. Firm C, which responds to only the price elasticity but not to the one-time-only nature of the sale, does only marginally better than Firm A, but very poorly compared to the rest of the firms. Thus, in OTOS situations, responding to the demand elasticity does not help much. This conclusion is also reinforced by the small differences in the $\%M_g$s of Firms B and D that differ from each other only in their response to the demand elasticity.

For most of the parameter values considered in Table 4, Firm B's $\%M_g$ is 93% or above. Note also that Firm B does not have to incur the additional implementation costs that Firms C to F must incur. This reaffirms the cost-effectiveness of Firm B's decision structure and criteria. In short, the sensitivity analysis reinforces all of the conclusions drawn from Tables 2 and 3. The sensitivity analysis also provides a few additional insights. For example, among all the parameters, the NPV_g values are most sensitive to the assumed value of d, the OTOS discount. As d increases, most firm's NPV_gs increase at a proportionately higher rate. Furthermore, the larger the d, the smaller are the $\%M_g$s.

Although Joglekar and Lee (1997) have suggested that 30% or greater OTOS discounts are rare, the last row in Table 4 suggests that when such discounts are real, Firms E and F's strategies may be substantially better than Firm B's strategy. Thus, in such situations, a retailer may want to consider at least a coordinated decision system, if not also the use of the NPV criterion. Similarly, Firm B's NPV_g and $\%M_g$ values are most sensitive to the assumed ε. The larger the ε, the farther is Firm B's NPV_g from Firm F's NPV_g. At ε = 8,000 units/dollar, Firm B's $\%M_g$ is only 86.74%. Hence, when faced with large values of ε, a retailer may want to consider at least a coordinated decision system, if not also the use of the NPV criterion. This is even more true when both d and ε are large.

Among the remaining parameters, Firm B's $\%M_g$s are most sensitive to the assumed ordering cost, S. The smaller the S, the smaller is Firm B's $\%M_g$. Hence, small values of S, may also require a retailer to consider a deviation from Firm B's strategy. Firm B's $\%M_g$s seem to be rather insensitive to assumed values of inventory carrying cost H, h, and i. The fact that they are least sensitive to i, reinforces the conclusion that, in OTOS situations, NPV considerations are not really important.

TABLE 4

Sensitivity Analysis

Factor Changed	Effects on Each Firm's NPV_g and $\%M_g$: A NPVg	A %Mg	B NPVg	B %Mg	C NPVg	C %Mg	D NPVg	D %Mg	E NPVg	E %Mg	F NPVg	F %Mg
None (Base case)	$2,144	13.68	$14,735	94.04	$2,310	14.74	$14,790	94.39	$15,627	99.73	$15,669	100
ε = *4000*	$2,624	11.85	$21,481	97.03	$2,827	12.77	$21,470	96.98	$22,081	99.74	$22,139	100
ε = *8000*	$1,518	16.80	$7,836	86.74	$1,657	18.34	$8,123	89.92	$9,010	99.73	$9,034	100
S = 50	$1,515	10.08	$14,074	93.62	$1,637	10.89	$14,209	94.52	$14,995	99.75	$15,033	100
S = 200	$3,035	18.79	$15,671	97.00	$3,256	20.15	$15,608	96.61	$16,110	99.72	$16,155	100
H = $0	$2,538	11.38	$20,831	93.41	$2,836	12.72	$21,064	94.46	$22,174	99.43	$22,300	100
H = $2	$1,890	15.54	$11,483	94.40	$1,997	16.42	$11,470	94.29	$12,145	99.84	$12,164	100
h = 0%	$2,530	12.38	$19,113	93.53	$2,695	13.19	$19,304	94.47	$20,339	99.53	$20,435	100
h = 20%	$1,894	14.82	$12,058	94.38	$2,054	16.08	$12,048	94.30	$12,754	99.83	$12,776	100
i = 10%	$2,316	12.75	$17,089	94.09	$2,484	13.68	$17,143	94.39	$18,133	99.84	$18,162	100
i = 20%	$2,005	14.53	$12,973	94.00	$2,168	15.71	$13,025	94.38	$13,750	99.63	$13,801	100
d = 10%	$1,072	25.68	$4,084	97.82	$1,101	26.37	$4,024	96.38	$4,172	99.93	$4,175	100
d = 30%	$3,216	8.83	$32,833	90.10	$3,654	10.03	$33,882	92.98	$36,211	99.37	$36,441	100

Base Case Assumptions:

c = $10/unit, S = $100/order, h = 10%/$/year, d = 20%

H = $1/unit/year, i = 15%/year, ε *= 6000 units/$.*

CONCLUSION

A one-time-only sale, or the equivalent situation of an impending price increase with one last opportunity to buy at the lower price, is a commonly encountered situation. Although several models for optimal responses to an OTOS are available, practicing procurement managers do not seem to be aware of those models or the benefits they promise. The classical OTOS models recommend the use of a special order quantity in response to an OTOS. Recently, Ardalan (1994 and 1995) added three new strategy elements to a retailer's possible response to an OTOS, namely, the use of a special price, a coordinated system, and the NPV criterion. While the costs of implementation of each one of these strategy elements may be sizable, given the enormous potential benefits suggested by Ardalan's numerical examples, this paper attempts to isolate and assess the benefits of the various strategic elements.

The behavior of six firms, each using a different approach to the determination of its optimal response to an OTOS, was modeled. The model, the numerical example, and the sensitivity analysis confirmed that a firm maximizing its NPV by using a coordinated decision system did the best. However, the firm that used a coordinated system and the AP criterion did almost as well. It was also found that when both a special order quantity and a special retail price were employed, the benefits of a coordinated decision system were not significantly greater than the benefits of an uncoordinated system. The benefits of the use of a special retail price were also marginal. Hence, considering the implementation costs of the various strategic elements, it was concluded that the most cost-effective strategy was that of a firm which used an uncoordinated system and the AP criterion to determine its optimal special order quantity. From a practicing manager's point of view, this finding is good news insofar as it implies that most firms need not modify their current decision systems or criteria. On the other hand, the analysis shows that firms whose procurement departments ignored the one-time-only nature of a sale might be foregoing significant improvements in their NPV potential. Thus, the recommendation is that a firm's Procurement Department should be vigilant about the one-time-only nature of an OTOS, and it should respond by using one of the many classical OTOS models to determine its special order quantity.

Finally, there are a few cautionary notes about the foregoing conclusions and a few directions for further research. First, the sensitivity analysis suggests that, in situations involving relatively large discounts, significant demand elasticity, and small ordering costs, a retailer using only a special order quantity may be substantially compromising his potential growth in profits and NPV. Although such situations are presumed to be rare, it would be appropriate to seek clear empirical evidence on (a) the typical ranges of values for these parameters, and (b) the frequency of the extreme values, particularly in terms of their simultaneous occurrence.

Second, ideally, one would like to see a model that formally incorporates a retailer's costs of (a) communicating a temporary change in the retail price (b) using a coordinated decision system, and (c) using the NPV criterion. Instead, this paper simply asserts that, in most companies, these costs are sizable. Empirical estimates of these costs and models that formally incorporate those estimates would also be desirable.

Consistent with the available literature, this paper restricts itself to an analysis of an OTOS for a non-perishable, non-obsolescent product. However, OTOS are perhaps more common for perishable and obsolescent products. Hence, formal models that consider those products would also be desirable. Of course, practicing procurement managers need not wait for the future research. This paper warns that if they continue not to use a special order quantity in response to a one-time-only sale, they may be foregoing significant improvements in their bottom lines.

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