ARTICLE IN PRESS

NORTH-HOLLAND

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Industrial Marketing Management xx (2004) xxx–xxx

INDUSTRIAL MARKETING MANAGEMENT

An optimization approach to business buyer choice sets: How many suppliers should be included?

Ralph G. Kauffman[a,*], Peter T.L. Popkowski Leszczyc[b,1]

[a]Department of Management, Marketing and Business Administration, University of Houston-Downtown, One Main St., Suite 1017-N, Houston, TX 77002, USA

[b]University of Alberta, 4-20F Faculty of Business Building, Edmonton, Alberta, Canada T6G 2R6

Received 30 March 2003; received in revised form 25 April 2004; accepted 30 May 2004

Abstract

In many new or repeat purchasing situations, business buyers must decide how many suppliers to consider (a "choice set") in determining which supplier(s) to actually buy from or contract with. This paper develops an optimization approach to determining the size of the choice set, taking into consideration buyer utility and search and evaluation costs. A theoretical model is developed for both one-time and repeat purchase situations. The model is estimated using empirical data received from bids received for procurement auctions. In these auctions, suppliers provide bids for steel pipe based on two product attributes (price and delivery time). Model sensitivity to small changes in parameters is also tested.

Keywords: Choice set; Optimization; Industrial purchasing; Industrial buyer utility

1. Introduction

A business buyer is frequently faced with either purchasing something that he/she has not purchased previously or renewing or reviewing a purchase arrangement for an item that he/she has purchased before. In either case, it must be decided how many firms to include in the group from which to select the supplier from which to buy. This situation will be referred to as the "choice set decision" and to the group of suppliers in the selection group as the "choice set." Market conditions and purchasing practice sometimes simplify the choice set decision. For example, there may be only one or a few possible suppliers for particular requirements, or single-sourcing or supplier prequalification may predetermine or limit the size of the choice set. In many purchase situations, these limitations are not present and the purchaser is faced with deciding how large the choice set should be or whether to expand or contract a set that may exist. This may be particularly true for commodity-type items where there are numerous suppliers and all offer comparable products or services. Present trends to buyer–seller partnerships and alliances, fewer vendors, and single-sourcing have not eliminated the need for determining choice sets. In fact, with the likelihood of larger proportions of supply coming from fewer suppliers, usually with multiyear contracts, the potential impact of a poorly configured choice set is much greater than for an individual transaction situation. In addition, trends toward Internet purchasing and other forms of e-procurement may lead to more opportunistic buying behavior and more concern about choice set inclusion. In particular, the substantial increase in online procurement auctions increases the salience of the choice set size decision, or the number of bidders to consider (Jap, 2002). In addition, there are many buying situations where size and/or product application, and ability to forecast needs vary from transaction to transaction, and/or where market conditions exhibit considerable variation over time. Examples of such situations include custom design and manufacturing, construction industries, and commodity-type products, such as many standard steel-mill products. In such situations, due to potential and unforeseeable changes in

* Corresponding author. Tel.: +1-713-221-8962; fax: +1-713-226-5226.
E-mail addresses: kauffmanr@uhd.edu (R.G. Kauffman), ppopkows@ualberta.ca (P.T.L. Popkowski Leszczyc).

[1] Tel.: +1-780-492-1866; fax: +1-780-492-3325.

0019-8501/$ – see front matter © 2004 Elsevier Inc. All rights reserved.
doi:10.1016/j.indmarman.2004.05.001

market conditions, long-term or single-source arrangements could result in commitment to obsolete technology or inability to take advantage of price reductions. Therefore, the need to configure choice sets recurs frequently.

While this problem has been addressed in the consumer situation by a number of researchers (e.g., Hauser & Wernerfelt, 1990; Roberts & Lattin, 1991), it has not been studied extensively for the industrial or business case. The interest in this question in the consumer case stems from the desire of marketers to determine strategies that will increase the probability that their brands will be added to consumer's choice sets. When a brand will or will not enter a consumer's choice set was addressed by Hauser and Wernerfelt (1990). Roberts and Lattin (1991) addressed the question of how large that set should be from a utility and cost optimization point of view. Business marketers have similar motivation as consumer marketers to determine why brands may be added to a choice set. However, for many consumer situations, the addition of one or several brands to a choice set may be of trivial concern because the cost of enlarging the set may be small. The same type of decision is faced by a business buyer and the cost of enlarging the choice set may or may not be small. Also of concern to the business buyer is the possibility of having too small a choice set and the accompanying risk of receiving lower quality, paying higher prices, or receiving poorer service than might be available from a larger choice set.

In a small survey by the authors, 58 purchaser respondents of a randomly selected sample from the membership of the Institute for Supply Management indicated that influences on the size of their choice sets vary considerably. Among the top influences were as follows: how soon the item was needed, importance of quality, importance of the item to achieving the goals of the company, and importance of price. In the same survey, respondents reported their average choice set size at approximately 4 with 74% reporting their average choice set size as 3 or less. These relatively small numbers agree with choice set sizes suggested in several purchasing studies. In these studies, the minimum choice set size was around 3 and was determined by ad hoc rules of thumb and individual experience (Crow, Olshavsky, & Summers, 1980; Erickson, Whittier, & Oswald, 1993; Vyas & Woodside, 1984). These studies and informal discussions with purchasers by the authors found almost no indication of any objective means of determining choice set size.

One may ask if there are situations that warrant an objective determination of choice set size, or if such a determination is possible and practical. Many purchase situations may indeed not justify objective determination, for example, purchase of commodity-type items with few if any product attribute or price differences, or infrequent purchases of low-valued items. These situations would not seem to offer much in the way of significantly increased benefits by increasing the size of the choice set.

In other situations, larger choice sets may offer large potential increases in benefits, relative to costs incurred by enlarging the choice set, due to high variability of market conditions and product offerings between suppliers and over time. In still other situations, while benefit increases from larger choice sets may be potentially significant, search and decision costs may be high. For example, purchases of unique or highly specialized products and services, such as construction projects or selection of an advertising agency. Both of these types of situations would seem to justify some objective means of determining choice set size. From a marketing point of view, the marketing mix strategies that will be most efficient for a given market or customer may vary depending on the number of suppliers that buyers consider or that they should consider to optimize the size of their choice sets. For example, in a situation that the marketer has determined as potentially beneficial for a larger choice set than the buyer is currently using, and for a customer who currently does not include the marketer in the choice set, the marketer could inform the buyer of the potential advantage of enlarging the set and create the potential to be included in the larger set.

It can be concluded from this discussion that (1) there may be situations where attribute and price differences between potential suppliers, and/or costs to find and qualify suppliers, vary sufficiently and are large enough to justify a choice set larger than the 3 or 4 that are currently commonly used; and (2) if larger choice sets are sometimes justified, there may also be justification to apply some objective means of determining the optimum set size.

The contributions of this paper are twofold: (i) based on theoretical concepts of buyer utility and decision-related costs as functions of choice set size, an optimum choice set size is derived for one-time and repeat purchase situations; (ii) using actual bid prices and search and decision cost data from the industrial steel pipe market, the optimum choice set size for that market is empirically estimated. The analysis in that example indicates that there is considerable potential for cost savings from use of an optimum set size compared to an ad hoc size of 3 or 4. In the following section, a brief review of the literature is provided, followed by a discussion of the theory and model. Finally, managerial implications are presented along with suggestions for future research.

2. Review of literature

While models of consideration and choice set formation have received considerable attention in consumer research, little research has been conducted for industrial buying situations. This may seem surprising because organizational buying centers are more likely than consumers to undertake formal and elaborate prepurchase studies of products, markets, and potential suppliers, and therefore, incur larger and more measurable search and decision costs. Moreover, organizational buying behavior is often considered to be more consistent with the rational utility maximization paradigm and, because large monetary transactions are frequent, opportunity costs can be substantial.

A significant amount of research has been conducted on the formation of consumer consideration sets. For a review of these studies, the reader is referred to Shocker, Ben-Akiva, Boccara, and Nedungadi (1991), and the special issue of the *International Journal of Research in Marketing* (Roberts & Nedungadi, 1995), and Roberts and Lattin (1997). Of most relevance to the research in this article are the studies by Hauser and Wernerfelt (1990) and Roberts and Lattin (1991), who have developed models of consideration set composition based on search/evaluation costs and buyer utility. Roberts and Lattin modeled overall consideration set membership and determined the optimum size of the consideration set as a function of brand utilities and consideration costs. They modeled individual household's choice sets for frequently purchased consumable goods, using scanner panel data. Hauser and Wernerfelt performed aggregate level analysis, studying the distribution of consideration set sizes, order-of-entry effects, asymmetric advertising effects, and competitive activities on choice sets. Their focus was on determining when a brand will or will not enter the consumer's consideration set. The objective in this article is to determine the optimum size of the choice set, not whether or not a particular brand will enter the set. The analysis in this article is started from Hauser and Wernerfelt's basic utility framework and then proceeds to development of an approach to determine an optimum choice set size.

In the organizational marketing literature, choice set research has largely been limited to studies which (i) have developed a theoretical framework of the overall buying process (see, e.g., Choffray & Lilien, 1978; Woodside, 1987), and (ii) studies which have looked at the actual consideration set process used by organizations, (see, e.g., Crow et al., 1980; Jackson & Pride, 1986; Parasuraman, 1981).

Crow et al. (1980) used protocol analysis to determine the number of brands/suppliers actually considered. They found that some buyers set a specified number of quotations to be requested and then include that exact number of suppliers. Other buyers request quotations from all suppliers that meet their initial criteria of acceptability, but require a minimum of three suppliers. The acceptability criteria are adjustable depending on the number of suppliers meeting them. Another study found that the minimum number of suppliers invited to bid was three and that choice set size criteria were adjusted depending on how many qualified suppliers were available (Vyas & Woodside, 1984). Other researchers have found the use of "approved vendor lists" among organizational buyers (Jackson & Pride, 1986; Parasuraman, 1981). Such lists, in effect, function as evoked, consideration, or choice sets depending on the level of detail developed or maintained. However, none of these studies looked at how many suppliers a buyer should optimally consider. A study by Weber, Current, and Desai (2000) looked at a special case of determining the optimal allocation of purchases among a number of suppliers, taking into consideration supplier capacities, past supplier performance, and other factors.

While the literature has generally been conceptual concerning choice and consideration sets, in the commercial marketplace, formation of these sets is a daily occurrence, whether or not consciously done, and whether objectively or intuitively determined. This is not to say that consumers do not optimize the size of their sets. Consider a commercial buyer attempting to buy a particular good that is available from 20 suppliers, and which the buyer knows from past experience, has significant price variation across the suppliers. Would the buyer contact all 20 sellers for a price quotation? Intuitively one would expect that some buyers would, but some, perhaps due to time constraints, would not. What determines how many suppliers a particular buyer would contact? In the consumer case, according to Roberts and Lattin (1991), "the consumer will continue adding brands to the set so long as the incremental expected utility exceeds the associated costs." The industrial buyer would likely behave similarly except due to time pressures would likely not add to a set sequentially but would want to know at the outset what would be the optimum set size or how to determine it. A buyer with sufficient time and expectation of sufficient benefits (e.g., likelihood of lower price) may contact all 20 sellers. Another buyer who is very pressed for time and/or has lower expectation of lower price may contact only a few. The pressure of other requirements on the buyer's time may enter the decision process causing the buyer to intuitively weigh the opportunity costs of various work tasks and allocate available time accordingly. The implication is that there is an optimum set size, but the optimum will vary depending on individual cost and benefit expectations and resource availability. In the organizational case, an organization can more likely quantify the primary determining factors and, perhaps more objectively determine an optimum choice set size.

3. Theory and model development

Choffray and Lilien (1978) proposed that the process of choice set formation proceeds through several levels: evoked set of alternatives (awareness), feasible set of alternatives (meeting of purchase requirements), followed by individual and group choice processes. What is proposed in this article is a means of configuring the feasible set into an optimum number of included suppliers.

The following generalized model of choice set size determination is proposed:

For a given purchase situation:

$$n = f(v, s, d, m, p, e)$$

where n = choice set size; v = number of known, available, qualified, suppliers; s = search costs to find and qualify suppliers in addition to v; d = decision costs to evaluate suppliers' offerings; m = market characteristics, for example, variability of attributes of suppliers' offerings and of prices, availability, and quality; p = existence of suppliers in addition to v; and e = unobserved variables, for example, emergency situations, importance of item.

It is assumed that all qualifiable suppliers would be willing to sell to any potential buyer. Obviously, the factor m would determine what, if any, benefit potential exists from increasing the size of the choice set. Various situations would include some or all of the identified factors. For example, a first purchase of an item might mean that $v = 0$. In an established purchasing situation, a repeat purchase might mean that $s = 0$.

The following assumptions are made: (1) the number of potential suppliers is not limited ($v>0$, $p>0$); (2) there is no overriding unobserved situation, such as an emergency (therefore $e = 0$); (3) there is variability in suppliers' offerings ($m>0$); and (4) search and decision costs exist ($s>0$, $d>0$), In general, search cost (s) and/or decision cost (d) will increase as choice set size (n) is increased (to expand the set, a buyer will incur s and whether or not the set is expanded, d will be incurred). In addition, with variation among suppliers' offerings, as n increases, the likelihood of including a supplier that would offer increased utility will increase at a decreasing rate (Stigler, 1961).[2]

With this conceptual background, a model of optimum choice set size is developed. Then, an empirical study of the situation is made and the model is estimated for a relatively homogeneous product manufactured to an industry standard in a competitive market where products may be differentiated mostly on price and availability, and potentially some differentiation based on service. In many commodity markets, prices and availability change continuously over time. For example, at a given time, various suppliers may have different asking prices depending on availability, their product cost, and their individual inventory situations. In such markets, purchasers do not know in advance availability or prices from individual suppliers. However, price ranges and ranges of other attributes can be obtained from previous purchase occasions or other information sources, such as industry data or other purchasers.

[2] Stigler (1961) finds that any time there is a frequency distribution of prices quoted by sellers, "if the dispersion of price quotations of sellers is at all large (relative to the cost of search), it will pay, on average, to canvass several sellers," and "the expected saving from given search will be greater, the greater the dispersion of prices." He also finds: "Whatever the precise distribution of prices, it is certain that increased search will yield diminishing returns as measured by the expected reduction in the minimum asking price," and " if a distribution of asking prices did not display this property it would be an unstable distribution."

3.1. Model of optimum choice set

The utility derived from a particular supplier is defined as a function of the level of the attributes of the supplier and the importance the buyer places on these attributes. This can be represented by a simple multiattribute model:

$$U_j = f(a_{ij}, W_i) \tag{1}$$

where U_j = the utility for supplier j; a_{ij} = expected value of attribute i for supplier j; and W_i = importance of attribute i.

The product attributes of the supplier consist of price, availability, and so forth. For many commodities, the weights or importance of attributes is relatively stable across purchase occasions. A simple additive compensatory model can be used to represent this relationship (more complex models can be used depending on the particular relationships between attributes):

$$Uj = \sum_{i=1}^{k} W_i a_{ij} \tag{2}$$

where k = the number of attributes for supplier j.

Such an importance-weighted-point approach to evaluating and comparing alternate sources of supply has been well-documented in the purchasing literature, for example (Mathers, 1996), and can be applied using decision analysis software.

First to be considered is the case of a one-time purchase, where a purchasing manager is faced with selecting a choice set. It is assumed that purchasers are utility maximizers, who form choice sets by trading-off expected benefits of having more suppliers to choose from against the search and decision costs incurred by their inclusion. Thus, as in the Hauser and Wernerfelt (1990) consumer model, the expected net utility of choosing from n suppliers equals the expected value of the maximum of the utilities of the suppliers in the set minus the search and decision costs for the n suppliers. Decision costs include the costs of evaluating and choosing one of the alternatives. The one-time purchase utility relationship is then:

$$U = E[\max(u_1, u_2, \ldots, u_n)] - \sum_{j=1}^{n} d_j - \sum_{j=1}^{n} s_j \tag{3}$$

where U = buyer's net utility; u_j = utility derived from supplier j; d_j = decision cost for supplier j; s_j = search cost for supplier j; and n = number of suppliers in the consideration set.

To be nontrivial, it must be assumed that markets are decentralized and that differences exist between suppliers, such as different marketing mix strategies at various times, and that the distribution of the expected utilities of different suppliers will reveal some degree of dispersion; for example, prices and other product attributes will vary within and over suppliers over time. Given dispersion of prices and other attributes across sellers, there will be potentially increased utility from consideration of more than one supplier, and diminishing returns to search (Stigler, 1961). To generalize, say one supplier at a time is independently selected from a particular size choice set, n, and let p indicate the probability of finding a better supplier (a greater utility) on each selection. Then the probability of finding a particular number of better suppliers (say the number that would incur a particular amount of search and evaluation cost) can be characterized as a binomial process, where the probability of finding k better suppliers from a choice set of size n follows the binomial distribution. Due to search and evaluation cost for large numbers of suppliers, it can be expected that the value of k will be relatively small. In addition, as the values of price and other utility-imparting attributes are overlapping among suppliers and spread over some finite range, it can also be expected that the probability of finding a better supplier (p) will be relatively small. For small values of k and p, the Poisson distribution can be used to approximate the binomial:

$$p(k;\lambda) = \frac{\lambda^k e^{-\lambda}}{k!}, \qquad k = 1,2,\ldots \tag{4}$$

where p = probability of k greater utility from n suppliers. In addition, the mean and variance of the Poisson distribution = $\lambda = np$.

The problem is to determine how many suppliers (n) to include in a choice set to provide a particular level of increased utility compared to, say simply selecting one supplier randomly. Thus, for each additional supplier considered, the probability of obtaining a better supplier (greater utility) by considering that additional supplier is:

$$p(1;\lambda) = \lambda e^{-np} \tag{4a}$$

This expression represents a decreasing value as n increases. Its particular shape depends on the value of λ. If the probability of selecting a better supplier follows this distribution (given equal probability of selection and independent selections of suppliers), this expression can be used to characterize the distribution of supplier attribute changes as the number of suppliers in the choice set increases.

Because the objective is to relate utility to the choice set size, n, Eq. (4a) is rewritten such that it, or the exponential in Eq. (4a), varies only with n. The notation is also changed, replacing λ with b:[3]

$$p(1;b) = be^{-cbn} \tag{5}$$

where c = a constant, such that $cb = p$.

Because Eq. (5) expresses the probability of obtaining a better supplier (greater utility) as n increases, it can be substituted for the utility portion of Eq. (3) which then becomes:[4]

$$U = 1 - be^{-cbn} - dn - sn \tag{6}$$

where "1" represents the maximum utility obtainable in a given purchase situation and the exponential term represents the proportion of that maximum utility obtained from various choice set sizes (n). For simplicity, it is assumed that decision (d) and search (s) costs are constant functions of the choice set size, and drop supplier subscripts.

The optimum number of suppliers (n^*) to choose from is obtained by taking the first derivative of the function in Eq. (6). n^* needs to be a positive whole number, and the discrete function is approximated by the continuous exponential function. Taking the derivative of Eq. (6) with respect to n, setting the result equal to zero and rearranging terms:

$$e^{-cn} = \frac{d+s}{cb} \tag{7}$$

Taking logs of both sides and rearranging yields the optimum number of suppliers as:

$$n^* = \frac{\log\left(\frac{d+s}{cb}\right)}{-c}$$

$$\text{s.t. } (d+s)n \le 1 - be^{-cn} \tag{8}$$

Subject to the rationality constraint that the total search and decision costs must be less than or equal to the buyer's utility or less than some maximum amount of cost willing to be borne by the buyer. The second-order conditions confirm that a maximum exists.

In situations of repeat purchases, the same assumptions apply as for a one-time purchase, but the future values of search costs are now discounted over multiple purchase occasions and a maintenance cost may be incurred to retain a supplier for future consideration. Therefore, Eq. (6) becomes:

$$U = 1 - be^{-cbn} - dn - \gamma sn - rn \tag{9}$$

where γ = the discount rate (10% is used as an example rate in the empirical analysis) and r = the maintenance cost per supplier.

[3] A constant, c, is introduced, such that $c\lambda = p$ and, replacing notation of λ with b (Eq. (4a)), becomes:

$$p(1;b) = be^{-cbn} \tag{5}$$

where $b = \lambda = np$ = mean and variance of the Poisson distribution; c = constant, such that $cb = p$.

[4] By focusing on existing products where the historical range of utilities is generally known, a value of "1" (or 100% of utility obtainable if a very large choice set is used) can be assigned to the mean maximum utility obtainable from consideration of multiple suppliers compared to that obtainable from one supplier. In other words, "1" represents 100% of the difference in utility between randomly selecting one supplier from a pool of qualified suppliers and the highest utility obtainable by considering larger numbers of suppliers. Utility is then represented by 1 minus the amount of utility obtained from different numbers of suppliers in the choice set and, as the choice set is increased, the less is subtracted from 1 and maximum utility is more closely achieved. In addition, the optimum number of suppliers needs to be a positive whole number. The discrete function is approximated by the continuous exponential function, including an integer constant.

Following the same procedure as for the one-time purchase, the optimum number of suppliers for the repeat situation is:

$$n^* = \frac{\log\left(\frac{d+\gamma s+r}{cb^2}\right)}{-cb} \tag{10}$$

subject to cost and rationality constraints.

3.2. Empirical analysis

In this section, an empirical illustration of the model is provided using data from an industrial commodity (steel pipe). First tested is the assumption of an exponential relationship between gross utility and the number of suppliers considered. Next, the optimum choice set size is determined.

For the commodity concerned, price and availability were identified by the buyer of this commodity as the major attributes determining buyer utility. First, utility is specified as a function of price only, next, this is extended to include availability. Thus, in this analysis, the buyer obtains maximum utility from the lowest price and quickest availability and some amount of disutility (search and decision cost) for each additional supplier considered.

The data used in this analysis consist of actual bid prices for steel pipe for 25 purchase occasions over a 1-year period. There were 8 to 10 bids per purchase occasion. Data were obtained from a company that buys quantities of steel pipe on a regular basis. Because the bids were from the same product class but for various sizes of the product, the data were standardized.

For each purchase occasion, the additional utility the buyer obtains from adding suppliers (increasing the choice set) had to be determined. To do this, sets of bids that were actually received simultaneously were adapted to simulate sets of increasing size. Simulation of different choice set sizes and calculation of incremental utilities were accomplished as follows: The analysis of each actual purchase occasion was started with a simulated choice set size of 1. Then, the set size was increased by increments of 1 supplier and it was determined what, if any, incremental utility resulted.[5] For each set size for each purchase occasion, the proportion of maximum benefit received was calculated.

[5] All bids were obtained simultaneously by the buyer. However, a sequence of bids is needed to simulate the incremental utility of obtaining more bids (enlarging the size of the choice set). Therefore, one of the bids (from the 8 to 10 obtained for each purchase occasion) is randomly selected and denoted to be a choice set of size 1. Next, a second bid is randomly selected from the remaining bids and this plus the first one selected is denoted to be a choice set of size 2, and so on until a sequence of set sizes is obtained for each purchase occasion. This process is used only to transform a series of simultaneously received bids into a sequential series of choice set sizes. Randomization assures that the process is unbiased.

3.3. Procedure used to determine the proportion of maximum benefit received

After increasing the choice set size (using the process described in footnote 5) to the actual set size for a purchase occasion, the maximum increase in utility between a choice set of 1 and a choice set with the maximum number of suppliers is determined. After doing this for all 25 purchase occasions, the difference between the maximum utility increase and that obtained for each set size up to the maximum is calculated. It is then possible to calculate the proportion of maximum benefit received for each set size for each occasion and also to calculate the mean proportion of maximum benefit for each choice set size. These means represent the proportion of maximum utility obtained as a function of the size (n) of the choice set.

To determine the utility obtained from each set size for each purchase occasion, the following approach was used:

(a) Determine the lowest price of all bids for each purchase occasion.
(b) Subtract that (lowest price of all bids) value from the price obtained from a randomly selected choice set of 1 to determine the maximum utility a buyer could realize by obtaining more than that one bid for that purchase occasion. This difference is designated as 100% of the maximum utility that could be obtained from multiple bids for that purchase occasion.
(c) Randomly select the second bid (making a choice set of 2) and compare to the first bid. If it is lower than the first bid, compute the percentage of maximum utility obtained by adding the second bid, and so on up to the maximum number of bids for each purchase occasion.

For example, if the lowest price out of 10 bids is \$4.00, and the first bid price (choice set of 1) is \$8.00, then the maximum utility from multiple bids for that purchase occasion is \$4.00. If the price of the next bid added (making a choice set of 2) is \$7.00, then the benefit obtained from a choice set of 2 compared to a choice set of 1 is \$8.00 – \$7.00=\$1.00. The proportion of maximum benefit obtained from a choice set of 2 is \$1.00, or 25% of the \$4.00 maximum utility determined above. Obviously, if the lowest price of any larger set size is equal to or greater than any smaller set size, the incremental benefit from that set size is zero.

3.4. Determining optimum choice set size based on competitive price offers

The starting point was to test the proposition that the gross utility (the expectation term on the right-hand side of the Eq. (3)) can be represented by the exponential function in the model. Therefore, the incremental utility data (mean proportion of maximum benefit for each number of bids) was expressed as a natural log function and regressed against the number of bids. Using OLS regression, estimates were obtained for the exponential parameters c and b in Eq. (6). The resulting parameters yielded an empirically estimated gross utility function:

$$\text{Cumulative utility} = 1.1889e^{-(.3449)(1.1889)n} \tag{11}$$

This estimated function and the actual utility from the empirical data are plotted in Fig. 1. There is a very close fit between the actual and empirically estimated data (R^2=.94), providing support for the posited exponential utility function.

Next, using Eqs. (8) and (10), the optimum choice set sizes were calculated for the one-time purchase case and for repeat purchases. The average search, decision, and maintenance cost per supplier were obtained from the same company that provided price data. The optimum number of suppliers to include in a choice set for this particular market for a one-time purchase was 9, and for a repeat purchase situation, 12 suppliers. Note that the number is larger for the repeat situation because, due to discounting the search cost, the cost function increases more gradually for the repeat situation than for the one-time situation (refer to Fig. 2). The optimization, subject to the rationality constraint and an integer constraint, was performed in Excel 2000. Fig. 2 shows the incremental net utility (utility after deducting decision and search costs) from considering additional suppliers, for both the one-time and repeat purchase situations. In this particular case, the "3-bid rule," reported by Crow et al. (1980), would have obtained only 61% of maximum benefit for the one-time purchase case and 64% for the repeat case. A criterion of achievement of 90% of maximum benefit would require a buyer of this commodity to obtain at least 5 bids for the one-time purchase case and 6 bids for the repeat situation.

3.5. Optimum choice set size based on price and availability

In this section, availability is added to the model. Availability is measured as the number of days until delivery. The metal pipe in this analysis is used in the construction of oil wells, and there is a trade-off between the price to pay and the time until delivery. As before, the incremental utility for availability from including additional suppliers in the choice set (additional bids) is calculated. Again, the parameters of the cumulative utility function were calculated, as in Eq. (11). However, in this case, utility is simply a weighted function of price and availability. After discussion with the purchasing manager at the source of empirical data, it was determined that for this commodity, price and availability are, in general, of equal importance. Hence, an equal weight is used for each. The resulting parameter estimates for the exponential function are as follows: $c=0.439$, $b=1.046$ with R^2=.95.

In a similar manner as above, the optimum choice set size is determined. When availability is added, the number of suppliers to include for a one-time purchase is 8 suppliers (9 with price only), and for a repeat purchase situation, 10 suppliers (12 with price only). These reductions are due to less variability in availability from different suppliers. These results are shown graphically in Fig. 3. Fig. 3 shows the net utility to the buyer for considering different numbers of suppliers. Again, it is clear that the "3-bid rule" leads to significant lower levels of utility to the buyer. Because adding availability had little impact on the decision and search costs, these remained the same. Next, the sensitivity

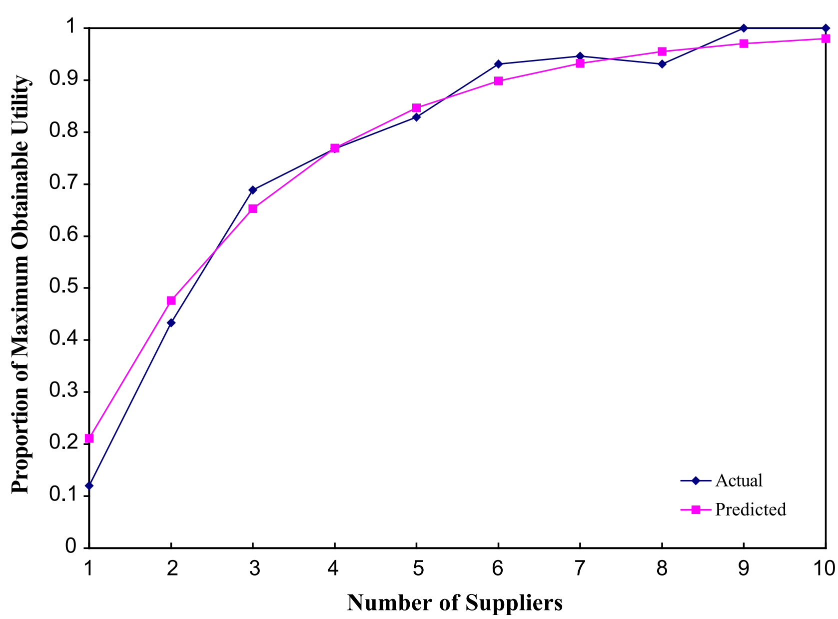

Fig. 1. Actual vs. predicted gross utility for one-time purchase (price only).

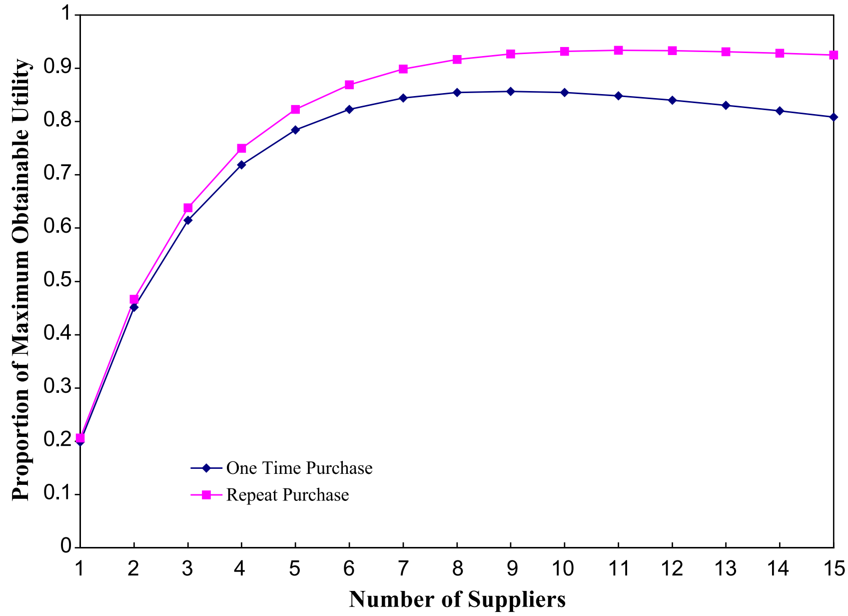

Fig. 2. Net utility obtained for different number of suppliers (price only).

of the results to changes in the model input will be examined.

3.6. Sensitivity analysis

Up to this point, it has been assumed that the purchaser could construct the gross utility function, and how to estimate the exponential parameters from historical knowledge of the distribution of prices and product availability was discussed. Next, uncertainty will be introduced into the model and its impact on the optimum choice set size will be determined. One way to add uncertainty is by varying the parameters of the exponential utility function. Changes in the parameters would result from variation in market situations and other differences in utility between available suppliers. Therefore, these results will provide the buyer with an indication of how sensitive results are to changes in market situations. To obtain an indication of sensitivity over a broad range, the variance and cost parameters were varied one at a time in the empirical example. Increasing the b parameter simulates more variance in attributes of supplier offerings. This analysis indicated that, as intuitively expected, when the variance of the distribution is reduced, the optimum number of suppliers is also reduced. As the variance of the distribution increases, the optimum number of suppliers increases, but is relatively insensitive to small

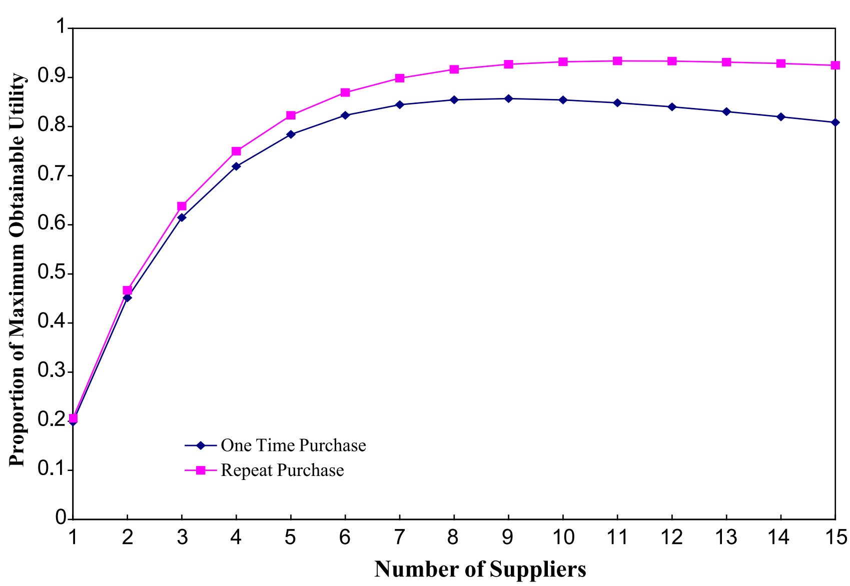

Fig. 3. Net utility obtained for different number of suppliers (price and availability).

changes in the variance parameter. For example, the number of suppliers for a parameter value of .75 of the estimated value in the repeat purchase case resulted in an increase of 2 in the optimum number of suppliers. A parameter increase to 1.25 of the estimated value resulted in a decrease of 1 in the optimum number of suppliers.

Also examined was the sensitivity of the optimum number of suppliers to changes in search and decision costs. Increases in decision and search cost, as expected, lead to smaller consideration sets and cost decreases have the opposite effect. The optimum is relatively insensitive to small changes in decision and search costs. For example, a cost decrease of 25% in the one-time purchase case resulted in an increase of 1 in the optimum number of suppliers. A cost increase of 25% resulted in a decrease of 1 in the optimum number of suppliers.

4. Managerial implications

The principal implications of this study for both organizational buyers and sellers are that for certain situations, the optimal number of suppliers for a buyer to consider should be analytically evaluated rather than be determined by some historical rule of thumb. By determining the benefits derived from considering multiple suppliers, it was possible to calculate the optimum number of suppliers from whom to obtain bids. In practice, the "3-bid rule" as often used, may lead to significantly lower levels of realized utility. Obtaining the optimum number of bids for a purchase occasion, and using price data from the actual situation of the empirical analysis, results in a mean benefit per purchase occasion of $3361 (in price savings alone), compared to the "3-bid rule." This leads to significant cost savings on an annual basis with over 100 purchase occasions annually in the empirical example situation.

Furthermore, the degree of increase in utility from consideration of multiple suppliers is affected by the variability in attributes of the offerings of different suppliers. Larger variability provides opportunity for greater cost savings with each increase in the choice set and leads to realization of potential utility with smaller optimum choice sets. If a product has a small variance (relatively flat utility curve) in the measurable utility-related attributes, such as price and quality, then the potential benefit from additional proposals will be relatively small. In such instances, difficult to measure buyer utility items, such as personal relationships and image, may have a greater influence on purchase decisions. These variations in utility are reflected in the parameter estimates. Sensitivity analysis was performed to determine the influence of changes in estimates on the optimum choice set size. Overall, it was found that the results are relatively robust to small changes in the parameter estimates and costs.

Once a purchaser has calculated the utility function, it is possible to perform sensitivity analysis and determine the optimum number of suppliers to consider when costs change. A possible strategy for a company is to calculate the optimum number of suppliers to consider and next perform sensitivity analysis based on often observed scenarios. This can be used as a guideline for different purchasing situations.

Analysis of consideration set formation and buyer utility can provide meaningful insights in determining marketing mix and transaction strategy on the parts of organizational buyers and sellers. For example, if a marketer can determine what attributes or utilities a buyer uses or would use to determine consideration set size, he/she can adjust his/her marketing mix accordingly. Sellers can also determine the likelihood of (informed) buyers considering relatively large or small numbers of suppliers in particular markets or product classes. This can indicate the relative importance of direct versus indirect utility-affecting factors in buying decisions, which, in turn, should influence marketing strategy and marketing mix decisions. Buyers can determine the potential benefit from inclusion of additional or fewer suppliers in their purchasing process.

4.1. Checklist for management actions

4.1.1. Marketers—to increase likelihood of inclusion in buyers' choice sets

– Determine key utility attributes used by buyers to include suppliers in their choice sets and adjust marketing mix accordingly for particular buyers.
– Determine which markets have the largest variability in key buyer attributes across suppliers.
– Target markets with large attribute variability, because choice sets are likely to be larger.
– For markets with small attribute variability, emphasize nonattribute factors, such as relationships.

4.1.2. Buyers—to determine optimum choice set size

– Identify key utility attributes for a particular purchase situation
– Obtain search, decision, and (for repeat purchases) maintenance costs and a discount rate, for purchase situations
– Estimate utility function parameters as described in this article, using historical or projected data for key attribute values
– Using the estimated parameters, calculate the optimum choice set size.

5. Limitations and future research opportunities

A simple model has been provided to determine the optimum choice set for an industrial commodity. While for this particular analysis, the assumptions made are quite realistic, future research should study other product classes, and relax the assumptions. An undifferentiated product, steel pipe, was studied. Future research should study differentiated products which will require the inclusion of other product attributes in the utility function. Another assumption made is that managers have prior information about the ranges of prices (which is the case in the empirical example in this article). Models can be developed which relax this assumption and which include uncertainty in the model. It was assumed that search and decision costs are fixed. There may be ''economies'' to search, which can easily be included in the model. Finally, it was assumed that consideration sets are fixed, and purchasers select a number of suppliers to choose from. In the example in this article, price quotes were obtained simultaneously. However, there are many instances where the search process is sequential. Sequential search with prior information will lead to far more complex models.

This model will be most applicable for purchase decisions for which there are significant search and decision costs, substantial differences between competing products, and the buyer is able to evaluate the alternatives. In certain instances, the choice set size may be inversely related to the ability to evaluate the alternatives. The selection of an advertising agency, for example, is a very involved task requiring significant search and decision costs. However, it is difficult to evaluate a priori the success of an advertising agency or a proposed campaign. In such instances, companies tend to seriously consider only a limited number of alternatives.

Most companies have prior information; for example, they know that certain suppliers offer goods or services which are generally cheaper or of better quality than other suppliers. The availability of prior information does not alter the basic problem. The main effect of prior information is that lists of acceptable suppliers or other information will reduce the size of the initial consideration set and also likely reduce search costs.

A simple additive attribute model was used. Only two attributes were included which are of equal weight. These weights are assumed to be constant for all purchase decisions. Depending on the type and the importance of particular purchases, these weights may fluctuate. Different attribute weighting can easily be built into the model.

Acknowledgements

The authors thank Paul Messinger, Ujwal Kayande, and participants at the University of Alberta seminar series for helpful comments and suggestions. Funding for this research has been received from the Social Sciences and Humanities Research Council of Canada, through both its Initiative on the New Economy Research Alliances Program (SSHRC grant 538-02-1013) and its Standard Research Grants Program (SSHRC grant 410-01-1332).

References

Choffray, J.-M., & Lilien, G. L. (1978, April). Assessing response to industrial marketing strategy. *Journal of Marketing*, *42*, 20–31.

Crow, L. E., Olshavsky, R. W., & Summers, J. O. (1980, February). ''Industrial buyers'' choice strategies: A protocol analysis. *Journal of Marketing Research*, *17*, 34–44.

Erickson, K. C., Whittier, R., & Oswald, M. (1993). Sourcing. In H. E. Fearon, D. W. Dobler, & K. Killen (Eds.), *The purchasing handbook* (5th ed.) (pp. 129–168). New York, NY, USA: McGraw-Hill.

Hauser, J. R., & Wernerfelt, B. (1990, March). An evaluation cost model of consideration sets. *Journal of Consumer Research*, *16*, 393–408.

Jackson, R. W., & Pride, W. M. (1986). The use of approved vendor lists. *Industrial Marketing Management*, *15*, 165–169.

Jap, S. D. (2002). Online reverse auctions: Issues, themes, and prospects for the future. *Journal of the Academy of Marketing Science*, *30*(4), 506–525.

Mathers, M. (1996, March). A weighty proposition. *Purchasing Today*, *7*, 16.

Parasuraman, A. (1981, Spring). Characteristics of firms with and without formal vendor evaluation systems: Implications for institutional buyers and sellers. *Akron Business and Economic Review*, 30–34.

Roberts, J. H., & Lattin, J. M. (1991, November). Development and testing of a model of consideration set composition. *Journal of Marketing Research*, *28*, 429–440.

Roberts, J. H., & Lattin, J. M. (1997). Consideration: Review of research and prospects for future insights. *Journal of Marketing Research*, *34*(3), 406–410.

Roberts, J. H., & Nedungadi, P. (1995). Studying consideration in the consumer decision process: Progress and challenges. *International Journal of Research in Marketing*, *12*, 3–7.

Shocker, A. D., Ben-Akiva, M., Boccara, B., & Nedungadi, P. (1991). Consideration set influences on consumer decision-making and choice: Issues, models, and suggestions. *Marketing Letters*, *2*(3), 181–197.

Stigler, G. J. (1961). The economics of information. *Journal of Political Economy*, *69*(3), 213–225.

Vyas, N., & Woodside, A. G. (1984, Winter). An inductive model of industrial supplier choice processes. *Journal of Marketing*, *48*, 30–45.

Weber, C. A., Current, J., & Desai, A. (2000). An optimization approach to determining the number of vendors to employ. *Supply Chain Management: An International Journal*, *5*(2), 90–98.

Woodside, A. G. (1987). Whom do customers think of first? In V. Kijewski, B. Donath, & D. T. Wilson (Eds.), *The best readings from Business Marketing Magazine (1993)* (pp. 57–61). Belmont, CA: Wadsworth.

Ralph G. Kauffman received his PhD in Management Science with a major in Marketing from the University of Texas at Dallas; his broad research interests include organizational marketing strategy, organizational procurement and supply management (particularly organizational choice processes), and the marketing–procurement interface in business transactions.

Peter T.L. Popkowski Leszczyc received his PhD in Management Science with a major in Marketing from the University of Texas at Dallas; his broad research interests include empirical and theoretical issues related to (internet) auctions; product bundling; consumer store choice and shopping behavior; and long-run effects of marketing mix variables.