Understanding Tradeoffs in the Supplier Selection Process: The Role of Flexibility, Delivery, and Value-Added Services/Support

Keywords: Supplier Selection, Empirical Research, Choice Processes

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ABSTRACT

In this study, we present, based on econometric choice modeling framework, how manufacturing managers/executives tradeoff between cost, delivery, flexibility, and service features in the supplier selection process for commodity raw materials, given acceptable quality. Empirical data for this study was collected from manufacturing organizations in Europe (Germany, France, Italy, United Kingdom) using a computer-based supplier selection discrete choice survey. Each survey instrument contained 16 supplier selection choice sets, which compared 23 attributes of the current suppliers with a "new" potential supplier. The attributes of new suppliers were varied across two to four levels using established factorial experimental design procedures. The resultant multinomial logit models show the relative impact of cost, flexibility, delivery and service features on supplier selection.

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INTRODUCTION

Over the last thirty years, supply chain management (SCM) and the supplier selection processes have received considerable attention in the operations management literature (Miller, Graham, Freeland, Hottenstein, Meredith and Schmenner, 1981). Several scholars have emphasized the multi-disciplinary nature of supply chains and suggested that the use of economics & marketing-based methods can further increase the effectiveness of SCM (e.g. Bankar and Khoska, 1995; and Karmarkar, 1996). For example, as outsourcing becomes more important in many industries, the supplier selection process does as well (Kannan and Tan, 2002; Yan, Chaudry, and Chaudry, 2003; Choy, Lee, and Lo, 2003; Choy et al., 2004, Li, et al. 2006). In addition, with the rapid proliferation of information sharing across supply chains, the importance of supplier management has been amplified during recent years (e.g. Fine, 1998; Hanfield and Nichols, 1999; Kaplan and Sawhney, 2000; Simchi-Levi, Kaminsky and Simchi-Levi, 2000; Hall and Braithwaite, 2001). A number of empirical studies also show that managers indeed consider the role of the supplier to be critical for superior business performance (e.g. Flynn, Schroeder and Sakakibara, 1994; Choi and Hartley, 1996; Vonderembse and Tracey, 1999; González, Quesada, and Mora Monge, 2004).

While the academic literature is very comprehensive, the effective evaluation and selection of suppliers for important raw materials continues to be challenging in many industries. In this context, the past research shows that firms use price and a number of other dimensions such as quality, flexibility, delivery, and service in the supplier selection process (e.g. Dickson, 1966; Hirakubo and Kublin, 1998; Li et al., 2006; Sarkis and Talluri, 2002; Verma and Pullman, 1998; Wilson, 1994). Broadly speaking, supplier selection tradeoffs correspond well with various competitive priorities identified by and explored extensively in the operations strategy research (e.g. Hayes and Wheelwright, 1984; Boyer and Lewis, 2002).

The supplier selection literature is also rich in terms of conceptual models, decision support systems, simulation studies, and empirical analyses related to the vendor evaluation (e.g. Pearn, Wu, Lin, 2004; Bhutta and Huq, 2002; Chan, 2003; Chan and Chan, 2004; Onesime, et al., 2004; Basnet and Leung, 2004; Valluri and Croson, 2005; Carter and Jennings, 2004; Kamann and Bakker, 2004; Lin et al., 2005). However, relatively little work has been done to integrate market-utility based approaches in the supplier selection processes as recommended by both classic and contemporary research in operations strategy (e.g Anderson, Cleveland, and Schroeder, 1989; Vickery, Droge and Markland, 1993, Boyer, Ward, and Leong, 1996).

Market utility-based approaches such as discrete choice analysis (also know as choice-based conjoint) can assess the relative weights of price, quality, delivery, flexibility, and various value-added features in various managerial decision making processes (e.g. Ben Akiva and Lerman, 1991; McFadden, 1986; Louviere, Hensher, and Swait, 2001, Verma, et al., 2008). These methods have seen wide applications in many social sciences including marketing, transportation planning, environmental resource economics, service design, and operations management (e.g. Green and Krieger, 1996; Pullman and Moore, 1999; Pullman, Verma, and Goodale 2001; Verma, Thompson, Moore, and Louviere, 2001). Examples of discrete choice and conjoint analysis in operations management include product line decisions (Yano and Dobson, 1998; Moore et al., 1999; Morgan et al., 2001; Michalek et al., 2005; Luo et al., 2005); optimal service design (Verma et al., 2001); and operations capacity planning (Pullman and Moore, 1999, Goodale et al., 2003). In addition, Verma et al. (2006, 2008), Ding et al. (2007) and Victorino et al. (2005) have applied discrete choice models in a variety of operational settings. Furthermore, an emerging emphasis on incorporating behavioral aspects into manufacturing and service operations models (Bendoly et al., 2006), portends future growth of discrete choice analysis and related approaches in the operations management literature.

As mentioned earlier, despite its advantages, discrete choice analysis has only been used in a few papers related to supplier selection. Specifically, Verma and Pullman (1998) presented a simple illustration of discrete choice analysis for supplier selection. They demonstrated that the managers' perceived importance of supplier attributes such as quality, cost, delivery and flexibility are not consistent with their actual choices. Li et al. (2006) extended the use of discrete choice analysis in supplier selection literature by comparing the attributes of an existing supplier to that of a new supplier. They also extended the theoretical framework to include supplier switching inertia. Our paper adds to the above stream of evolving literature on the use of discrete choice analysis in the supplier selection process.

In this paper, we explore how executives tradeoff amongst various competitive dimensions when selecting a supplier for important but commodity raw materials. The empirical context of our study is based on a commodity (aluminum profiles used in a variety of manufacturing industries) where quality is assessed as "conforming to specifications" and therefore is a necessary requirement or order qualifier for competing but is not an order winner. Based on literature review, it is our impression that supplier selection of such context has not been studied in detail before.

Hence, in this experimental empirical study (details provided later) we assess the managerial tradeoffs for cost, delivery performance, flexibility, and value-added service/support in a supplier selection process using a market-utility-based approach (discrete choice analysis). Specifically, we address the following research issues:

Research Objective 1: How do managers tradeoff between price and other competitive dimensions when choosing a supplier for commodity raw materials, given acceptable quality?

Research Objective 2: What is the relative importance of value-added service and support when choosing a supplier for commodity raw materials, given acceptable quality?

Similar research questions have been addressed in past research. However, as mentioned earlier, with the exception of two papers, a market-utility-based approach has not been used to assess tradeoffs in the supplier selection process. Our study also demonstrates a new approach for discrete choice analysis suggested by Li et al. (2006), which allows us to compare potential new suppliers with the existing supplier, thereby isolating the associated tradeoffs accurately.

Furthermore, in today's business environment with the possibility to source raw materials from almost anywhere in the world, it is possible that cultural/national differences exist with-respect-to supplier evaluation and assessment (e.g. Hofstede, 2003; Schroeder and Flynn, 2001). Therefore after conducting the primary study in one country (Germany) we collected small samples of additional data from three other countries in Europe (United Kingdom, France, Italy). The supplementary dataset will also use to explore the following research issue:

Research Objective 3: How do tradeoffs in the supplier selection process differ across cultural/national regions?

The rest of the manuscript is structured as follows: first, we review past research in supplier selection analysis. Second, we describe the research design including an overview of the discrete choice analysis followed by the results of an empirical study conducted in four languages in Europe. Finally, we discuss the research and managerial implications of our work.

LITERATURE REVIEW

In one of the early studies based on empirical data collected from 170 purchasing managers, members of the National Association of Purchasing Managers, Dickson (1966) identified over twenty attributes which managers generally consider when choosing a supplier. Following this exploratory study, a great number of articles focused on supply chain management and supplier selection criteria specifically. We discuss a number of these articles in this section, starting with the conceptual and review papers, followed by empirical research, decision support system papers, simulation studies, and finally supplier evaluation and selection modeling papers.

Conceptual and review papers

A number of conceptual papers have been published in the last decades that emphasized the strategic importance of the supplier selection process and evaluated the relative importance of quality, cost, delivery performance, and other supplier attributes in the supplier selection process. (e.g., Cardozo and Cagley 1971, Sheth 1973, Dempsey 1978, Ansari and Modarress 1980 & 1986, Monczka et al. 1981, Hahn et al. 1983, Jackson 1983, Kraljic 1983, Browning et al. 1983, Treleven 1987, Burton 1988, Bernard 1989, Wagner et al. 1989, Benton and Krajewski 1990, Chapman 1993). The interested reader is referred to a handbook of logistics and supply-chain management (Brewer et al. 2001) or Weber et al. (1991) for a general overview of the supplier selection literature.

Empirical research

During recent years a number of empirical articles have been published which address supplier selection issues in specific industries and/or present a comparison between two or more industries. For example, Mummalaneni and Dubas (1996) presented the results of an exploratory study examining the trade-offs made by Chinese purchasing managers among six performance measurement attributes. Pearson and Ellram (1995) examined supplier selection and evaluation criteria in small and large electronic firms in the United States. Swift (1995) presented criteria used by purchasing managers in selecting single suppliers. Lambert and Adams (1997) presented an empirical review of attributes traditionally used by purchasing managers in supplier selection in the hospital setting. Hirakubo and Kublin (1998) examined the purchasing behavior in he electronics components industry in Japan. Kuochung and Ding (1995) examined the effects of culture on the industrial supplier selection process in China and Taiwan. Robb et al. (2008) focus on manufacturing strategies in China, and Amoako-Gyampah and Acquaah (2008) in Ghana.

Patton (1997) addressed tradeoffs in individual and joint selection decision-making in the industrial supplier selection process. Ittner and Larcher (1999) examined the relationship between supplier selection, monitoring practices, and organizational performance, while Liao and Rittscher (2007b) develop a multi-objective programming model which includes a supplier selection component. Carter and Jennings (2004) studied corporate social responsibility in the purchasing function context. Lin et al. (2005) showed that quality management practices are significantly correlated with supplier selection strategies. And finally, Gonzáles et al. (2004) investigated the importance of supplier selection in the quality of the final product and determined that it is in fact the most significant variable.

Decision support system papers

Most often a manufacturer has multiple suppliers to choose from and has to make a decision based on multiple variables. To accommodate this decision, Weber and Current (1993) proposed a multi-objective approach to supplier selection which provides a useful decision support system for a purchasing manager faced with multiple suppliers and tradeoffs such as price, delivery reliability, and product quality. Alternatively, Pearn et al. (2004) developed a process capability index (C_{pm}) which collapses all the decision variables into a single index, which simplifies the supplier decision, while Huang and Keskar (2007) provide a supplier selection method which takes into account the firm's business strategy.

Perhaps the most used decision support system for supplier selection is the Analytical Hierarchy Process (AHP). An application of the AHP to the supplier selection process was first described by Barbarosoglu and Yazgac (1997), and it has subsequently been compared with the Total Cost of Ownership (TCO) method (Bhutta and Huq 2002), applied on vendor selection (Chan 2003), used to tackle multi-item/person/criterion decisions (Chan and Chan 2004) and used along with the Grey rational scale by Tseng and Lin (2005) to rate suppliers. Talluri et al. (2006) proposed an integration of the TCO and the AHP approaches for selecting appropriate suppliers. Also, Wang et al. (2004) use a combination of AHP and preemptive goal programming (PGP) to both qualitatively determine which supplier to use and mathematically determine the optimal order quantity from the chosen supplier.

In addition to combining the AHP approach with other methods, Chan and Kumar (2007) extended it by including risk factors involved in global supplier selection. Their fuzzy extended analytic hierarchy process (FEAHP) is an efficient tool to handle the fuzziness of the data involved in deciding the preferences of different decision variables. Chen et al. (2007) also employed a hierarchical model using triangular fuzzy numbers to deal with supplier selection problems.

Simulation studies

A number of simulation studies with a focus on the supplier selection process have also been published. For example, Crama et al. (2004) formulated a non-linear 0-1 programming problem with complex quantity discounts offered by different suppliers and alternative product recipes. Cakravastia and Takahashi (2004) created a simulation model to determine which supplier to select for business and the volume assigned to each of those suppliers. Finally, Basnet and Leung (2005) created a simulation model to determine what products to order in which quantities from which supplier in which periods to satisfy a given demand stream.

Supplier evaluation and selection modeling papers

It is desirable for firms to select a supplier that excels in most of the supplier evaluation criteria. At the same time, it is unlikely that any one supplier can excel in all or multiple evaluation criteria at a reasonable cost. Consequently firms have to tradeoff between price, quality, and other value-added features when choosing suppliers for key components and raw materials. To address this complex multi-criteria managerial decision-making problem, a variety of supplier evaluation and selection models have been developed. For example, Vokurka and Choobineh (1966) developed a prototype expert system for evaluation and selection of potential suppliers. Patton (1996) explored the impact of human judgment models in combination with multi-attribute supplier evaluation methods. Rosenthal and Zydiak (1995) and Sarkis and Semple (1999) addressed the issue of bundling multiple stock items on purchase costs and subsequently on supplier selection. Karpak et al. (1999) presented a visual interactive goal programming procedure that assists purchasing teams in the supplier selection process. Petroni and Braglia (2000) proposed an alternative decision model based on purchasing managers' periodic evaluation of the supplier using a principle components analysis. Masella and Rangone (2000) proposed a contingency approach for supplier selection depending on the time frame and the content of co-operative customer/supplier relationships, while Prahinski and Benton (2004) investigated how suppliers perceive the buying firm's supplier evaluation communication process and what its impact is on the suppliers' performance, and Araz and Ozkarahan (2007) focus on the long-term effects in selecting suppliers.

Eltantawy et al. (2003) and Sharland et al. (2003) both examined the role of cycle time to supplier selection and performance. Braglia (2000) developed a data envelopment analysis-based model for formulating sourcing strategies in changing marketplace. Degraeve, et al. (2005) proposed a mathematical programming approach known as Total Cost of Ownership perspective which allegedly outperforms other multi-criteria supplier selection models and combined this later with Activity Based Costing (Roodhooft and Konings, 1997) in a case study.

In summary, without claiming that we have presented an exhaustive list of references in the above, it is evident that the supplier selection literature boasts an abundance of conceptual and review, empirical research, decision support systems, simulation studies, and applications of multi-criteria decision-making technique papers. We contribute to this stream of research by illustrating the usefulness of discrete choice analysis in evaluating the relative impact of various value-added features in the supplier selection process in a multinational environment.

RESEARCH METHODS

To explore the research objectives listed earlier, we designed a computerized experimental supplier selection study using discrete choice analysis. The respondent population consisted of manufacturing companies located in four European countries – Germany, United Kingdom, France and Italy. The primary sample was obtained from Germany where larger numbers of manufacturing firms were the users of aluminum profiles as raw materials. Secondary samples were obtained from the other three countries for the purpose of cross-cultural comparisons.

The list of the manufacturing companies was obtained from a European trade association of business-to-business (B2B) firms which use aluminum as the primary raw material in their manufacturing processes. Since there are generally accepted industry guidelines for metals, the "quality" is considered an order qualifier rather than an order winner when selecting a supplier for commodities (e.g., aluminum which does not meet industry criteria is simply rejected). Furthermore aluminum is used as a primary raw material for companies that manufacture a variety of products in a wide rage of industries, and therefore their supply represents an ideal empirical context for our purposes. The reader should note that we verified the industry practice by interviewing a number of executive and industry leaders across many different firms (additional details about data collection is provided later in this paper).

Approach

In order to understand the tradeoffs in the supplier selection process, one needs to consider the relative weights that buyers attach to various characteristics of their current supplier with respect to other competitors. When faced with a supplier selection choice task, decision-makers (purchasing managers and executives) are likely to consider features/characteristics of their current suppliers that they are already familiar with and also new features/characteristics that are made available to them by potential suppliers (Bettman, Capon, and Lutz 1975; Lancaster, 1966; Lynch et al, 1988). At the same time, it is generally not possible for any supplier to excel in all criteria considered by the buyer at the best possible price (e.g., Li. et al. 2006). Therefore, the buyer has to make trade-offs when faced with a choice between staying with the existing supplier and switching to a new supplier. Hence we used discrete choice analysis, which is an effective method for determining the relative weights assigned by decision-makers to components of decision criteria (Ben-Akiva and Lerman, 1991; Louviere and Woodworth, 1983; McFadden, 1986).

Discrete choice analysis (DCA) provides a systematic way to identify the implied relative weights and tradeoffs revealed by the choices of decision makers (e.g., a purchasing executive). DCA has been used to model choice behavior in many business and social science fields, and introductions to and extensions of DCA can be found in sources cited above and others such as McFadden (1986), Hensher and Johnson (1981), Green and Krieger (1996), and Guadagni and Little (1983). Econometric models developed from a DCA study can link determinant supplier attributes to decision-makers' (e.g. buyer) preferences. Therefore, by describing a supplier in terms of appropriate attributes, DCA can be used to predict market impact of competitors in a given environment. In particular, research suggests that after acquiring information and learning about possible alternatives (e.g., current and new potential suppliers), decision-makers define a set of determinant attributes to use to compare and evaluate alternatives. They then form impressions of each alternatives' position on the determinant attributes, value these attribute positions vis-àvis one another (i.e., make tradeoffs), and combine the attribute information to form overall impressions of each alternative.

It is now well-known that within the discrete choice framework the conditional probability of choosing an alternative in a choice set can be expressed as a multinomial logit (MNL) model (McFadden 1986). Execution of discrete choice analysis requires careful design of product/service profiles (e.g., a specific supplier of aluminum) and choice sets (e.g., a group of potential suppliers) in which two or more alternatives are offered to decision-makers (e.g., buyers), and they are asked to evaluate the options and choose one (or none). Each respondent in a DCA experiment receives several choice sets to evaluate (e.g., 8 to 32 sets) with two or more hypothetical services to choose from in each set. The design of the experiment is under the control of the researcher, and consequently, the decision-makers' choices (dependent variable) are a function of the attributes of each alternative, personal characteristics of the respondents, and unobserved effects captured by the random component (i.e., unobserved heterogeneity or omitted factors) (Louviere and Woodworth, 1983; Verma, Thompson and Louviere, 1999; Verma, et al., 2008).

DCA applications based on choice experiments typically involve the following steps: (1) identification of determinant attributes, (2) specification of attribute levels, (3) experimental design, (4) presentation of alternatives to respondents, and (5) estimation of the choice model. Past studies have shown that in general the market predictions generated from the statistical models based on discrete choice analysis are extremely accurate (e.g., Verma et al., 2008).

Experimental supplier attributes

Louviere, Hensher and Swait (2000) suggest that one should consider the following when building a list of attributes for discrete choice experimental design: (1) Is it necessary to include an exhaustive list of all salient attributes? (2) Which attributes can be retained, recombined, or re-expressed to keep the set of attributes as non-redundant and as small as possible to make the experiment tractable but realistic? They suggest that great care must be taken to ensure that all (or at least as many as possible) of the determinant decision attributes are identified and expressed in terms understood by the decision-makers to be studied. They recommend use of qualitative surveys, interviews, case studies, and/or focus groups to identify a set of relevant attributes along with reviews of practitioner and academic literatures.

In order to develop a comprehensive list of aluminum supplier attributes, we first collected in-depth qualitative information from plant level and corporate senior executives of both buyer and supplier organizations responsible for supply chain purchasing, production and corporate responsibilities. We conducted a number of interviews and group discussion sessions in addition to reviewing both academic and practitioners' literature related to the topic. These qualitative focus groups and interviews were conducted across four European countries (Germany, United Kingdom, France and Italy) in local languages.

Based on information collected during the qualitative research phase described above, we developed an initial list of supplier attributes and their levels. This list was distributed to all the executives and also to some new executives for additional feedback and edits. Based on their responses the list of attributes was modified for content, wording, and comprehensiveness. After four similar iterations the final list of supplier attributes/levels was considered acceptable by most executives and by members of our research team.

Table 1 lists selected supplier attributes, their levels, and their classification into four broad conceptual categories (Cost, Delivery Performance, Value-Added Service/Support, and Flexibility). The ***Value-Added Service/Support*** category was further sub-divided into two sub-groups: Services – which was comprised of three attributes (problem-solving services; online ordering service; assembly service), and Support – which was comprised of four attributes (risk management; vendor managed inventory; engineering consulting; and order tracking). The ***Flexibility*** category was sub-divided into three groups: Production Flexibility – which was comprised of four attributes (supplier's experience with different types of aluminum alloys; flexibility in manufacturing standards; manufacturing tolerances; and flexibility in providing additional manufacturing capabilities), Demand Flexibility – which consisted of four attributes (ability to rush orders; get small and large size orders; change annual demand; and flexibility in order proposal submission), and Variety – which was also comprised of four attributes (type of packaging, format of packaging, type of products offered, and range within each type of product offering). See for example also Liao and Rittscher (2007a), who focused specifically on the issue of supplier flexibility. The ***Delivery Performance*** category included three attributes (speed of prototype delivery, lead time, and variability in on-time delivery performance) and ***Cost*** included only one attribute – price. Table 1 lists the conceptual categories, and attributes used in the study.

[Insert Table 1 about here]

To create realistic supplier choice experiments, two to four realistic levels for each of the 23 identified supplier attributes were identified. Again we used the guidelines established by the discrete choice methodology literature (e.g., Ben-Akiva and Lerman, 1991) when developing levels for the final list of experimental attributes. While the descriptions of levels of attributes are specific to the aluminum industry, the conceptual categories and most of the attributes described above are fairly general. Therefore, in this paper we predominantly limit the discussion to broad supplier selection categories and higher-level attributes.

Experimental design

As described in Table 1, a total of 23 experimental attributes, each with 2 to 4 levels, were identified after the qualitative research stage. As is common practice in DCA with large number of attributes, we used fractional factorial design procedure to develop 64 orthogonal supplier profiles, which could allow the estimation of main effects for all attributes (Louviere, Hensher, Swait, 2000). To enhance the realism of the task, a full-profile approach was used in presenting the choice sets (Green and Srinivasan 1990), i.e., each profile shown to the respondents simultaneously described some combination of all the attributes. The resulting 64 experimental supplier profiles were divided into 4 statistically equivalent sets of 16 profiles each, since evaluation of 64 profiles is too many for one respondent. Later each respondent was randomly assigned to one of the four sets and was asked to respond to 16 choice tasks as described below.

The supplier selection choice task was formulated as a comparison between a respondent's "current" supplier and an "alternative" supplier generated experimentally. To be able to implement such a choice task it was necessary to first ask the respondent to describe the levels for each experimental attribute for their "current" supplier. Note that the description of "current" supplier can be unique to each respondent. Therefore the resulting choice experiment was unique to each respondent. As mentioned briefly in the introduction section, this methodological advance (comparison of an experimentally designed new supplier with each respondent’s current supplier) allows for the unique tailoring of the choice experiment to the respondents’ unique decision-making situation.

Implementation of the “current” versus “new” supplier choice experiment then requires that we keep track of respondents’ answers and then incorporate them within the choice experiment. Therefore we developed a database-driven survey system to keep track of each individual’s responses about their current supplier and then later presented them alongside the experimentally generated “new” supplier profiles. Such an experiment could not have been conducted using a traditional paper and survey instrument. Therefore, the survey was done via computer so that each survey could be customized.

We pre-tested the choice experiment with the group of executives who participated in the qualitative research and also with 10 new respondents. Based on their feedback, the working and layout of the survey was slightly modified to enhance clarity and realism of the choice tasks. In addition to the supplier selection choice task, the survey instrument included demographic questions about the respondents (e.g., age, gender, education, work experience) and background information about the respondents’ organization.

Data collection

The invitation to participate in the survey was sent to executives in approximately 350 manufacturing companies in four European countries (Germany, France, United Kingdom, and Italy) which buy and use aluminum as a raw material in their factories. The majority of the companies in the database were located in Germany (approximately 225), while the others were scattered across the remaining three countries. Senior executives with purchasing/supplier selection responsibility, such as Purchasing Managers, Plant Managers, Operations Managers, VP for Manufacturing/Supply Management (or similar), were contacted by phone and were requested to participate in the survey. The participants had the opportunity to obtain a copy of the summarized results and monetary incentives by participating in the survey.

After recruiting potential respondents by phone, we sent them access to the computerized survey in their own language (German, English, French, or Italian). Those respondents that did not answer the survey within the next 2 weeks were reminded by both phone and email. The resulting response rate for all the executives who had agreed to participate in the survey was approximately 65%. We would like to emphasize that the data collection for this project was quite expensive and a rather time-consuming process. In addition, the design and development of the individually customizable choice experiment (current vs. new supplier) required extensive programming. To check for a non-response bias we compared the responses of early and late responders. Since we only had contact information for the non-respondents we could not statistically compare the demographic characteristics of respondents to non-respondents. At the same time, the distribution of organizations and respondents is quite broad (based on several criteria such as size, geographical region, education, etc.) and therefore appropriate for the purposes of our study.

RESULTS AND ANALYSIS

In this section we describe the data analysis and choice modeling results. We first provide a description of sample characteristics followed by analysis of supplier section choice exercises.

Sample Characteristics

Descriptive statistics about the respondent pool are summarized in Table 2. Of the 200 completed (after discarding incomplete surveys) responses, approximately 72% of respondents were from Germany, 9% from the United Kingdom, 6% from Italy and 12% from France. Ideally, we would have liked to get equal number of respondents from each of the four countries; however, the original database included the majority of listings from Germany, the source of our primary sample.

Furthermore, we did not find any evidence of response bias based on the country the respondent belonged to. Table 2 also shows the wide range of industries the respondents operate in. The two largest industrial sectors were transportation equipment manufacturing (23.5% respondents) and industrial machinery and equipment manufacturing (21.5% respondents) followed by electronic equipment manufacturing (15.5%) and building components manufacturing (14%). The remaining approx 30% of respondents were distributed across a various other industries which use aluminum as raw material. The job title of respondents varied and approximately 55% of the respondents were purchasing officer followed by plant engineer (11%), plant or business unit manager (8%).

[Insert Table 2 about Here]

The annual usage of aluminum shows an interesting U-shape relationship as approximately a quarter of the firms use either less than 10 tons of aluminum (26.5%) or between 100 and 1000 tons (25,5%), while only 8% uses 20 to 50 tons of aluminum a year. When asked about how important aluminum raw materials were for their production processes, 57% of the respondents replied that it was a critical component (the remaining 43% checked on the box marked "used in production process but not critical"). About 90% of the respondents mentioned that the aluminum raw materials used in their production processes required some form of customization from the supplier. When asked where the buyers purchase their raw materials, approximately 50% replied that they get aluminum directly from the manufacturers of the components needed; approximately 30% purchased from general and specialized distributors; the remaining 20% were distributed amongst catalog/mail order supplier, internet-only supplier, local distributor/re-sellers and miscellaneous suppliers. The majority of the respondents (86.5%) mentioned that they receive shipments of aluminum at-least once / month.

Supplier choice analysis

The primary analysis approach associated with discrete choice analysis (DCA) is the estimation of the multinomial logit (MNL) models based on a maximum likelihood estimation technique (equations 1 and 2). We used the LIMDEP program to estimate three supplier selection MNL models: one for all the respondents (the complete model), one for only the German respondents, and one for the other three non-German countries from which data was collected. All of the estimated models were found to be statistically significant at the 5% level and the necessary goodness-of-fit measures (log-likelihood ratio; McFadden's ρ^2) show excellent statistical properties (Ben-Akiva and Lerman, 1991; Louviere, Hensher and Swait, 2001). Similar to ordinary least square regression, MNL models are derived by estimating β weights for all independent variables included within the model. The difference between the highest and the lowest levels of an attribute represents the "main effect" of the attribute on the dependent variable (supplier choice). Furthermore, according to Swait and Louviere (1993), the scale parameters (μ in equation 1) within each estimated model are different from each other because of differences in inherent variability within different samples. Therefore, as recommended by Swait and Louviere (1993), we re-scaled the models using a chi-square χ^2 test-based procedure so that the estimated weights across models can be compared to each other. Hence, for the sake of clarity, the results in this paper are presented in easy-to-follow graphical and more descriptive format. Detailed statistical results are available from the authors upon request.

Recall from Table 1 that we identified four conceptual categories (Cost, Delivery Performance, Value-Added Service/Support, and Flexibility), each with one or more subgroups, which in turn consisted of multiple attributes. Table 3 shows the main effects for the seven subgroups in decreasing importance, while Figure 1 shows these seven in a pie chart and grouped by the four conceptual constructs. The relative sizes of the fractions represents the value of each of the seven subgroups and are derived from the main effects of the constituent attributes (the main effects of all attributes included within each constructs were added together to get the composite score for each subgroup).

[Insert Table 3 and Figure 1 about here]

The most interesting observation with regards to our third research objective (international differences) can be found in Table 3: even though the Cost is the least important out of the seven subgroups, it is also the only construct to which the non-Germans attach a higher importance than the Germans. Furthermore, Figure 1 shows that overall the respondents almost attach as much weight to the Flexibility category as to all the other categories combined.

Figure 2 shows the differences between the German and the non-German respondents for the attributes in four of the subgroups (Production Flexibility, Value-Added Support and

Services, and Cost). Finally, from Figure 3, which shows the main effects for the individual attributes of the complete model, we see that the manufacturing tolerances attribute is the most important, ahead of the price.

[Insert Figures 2 & 3 about here]

In Figure 2 we see that in general the German respondents attach more weight to most of the attributes, but that this does not hold for the price attribute as also shown in Table 1 with the cost category, and that this difference is most evident in the manufacturing tolerances attribute. From Figure 3 we learn that even when we investigate the individual attributes, price is not the most important, but rather the manufacturing tolerances attribute (followed by the price, product range, and engineering consulting attributes). Thus, in the commodity raw material market, it is naturally very important to offer a low price, but this is definitely not the only important attribute.

CONCLUDING REMARKS

Leading publications in business management emphasize the need for understanding manufacturing and supply-chain related decisions and practices for improving the competitive position of a firm. Various publications argue that it is necessary for these managerial decisions and choices to be consistent with the corporate strategy for effective operations management. The objective of this research was to understand one strategic operating decision area: the supplier selection process. As more manufacturing organizations adopt extended-enterprise concepts, the role of supplier and supply chain management becomes even more important.

Our study was designed primarily to study how managers' tradeoff among cost, value added, delivery performance and flexibility attributes when choosing a supplier for major components and/or raw materials, given acceptable quality. The results presented in this paper have important implications for operations strategy and supply chain management research.

We found that overall the managers valued the suppliers' Flexibility the most, and in particular the attributes of manufacturing tolerances, product ranges, acceptance of small orders, and expertise with the use of alloys. Flexibility was followed by the Cost variable in importance; especially respondents from Italy (and to a somewhat lesser degree those from France and the U.K.) indicated that the price was very important in the supplier selection process.

Thus, our results do not only show which attributes are important in the supplier selection process, they also show a level of agreement with previous studies in cultural differences (Hofstede 2003, and Schroeder and Flynn 2001). In this context it is interesting to note that although the Germans valued the cost subgroup as the least important out of the seven subgroups; the other respondents valued this attribute as the third most important overall.

Furthermore, our research shows some interesting differences with past research. First of all we used the discrete choice analysis approach in an innovative way as we had our respondents choose between their current supplier and a hypothetical new one, a method to our knowledge never applied before in the supplier selection literature. Also, past literature mostly agrees that Quality, Cost and Delivery Performance are the most important variables when selecting a supplier (except for Verma and Pullman 1998), while in our research the Quality was assessed as "conforming to specifications" and therefore not part of the attributes. As a result, we found that Flexibility was the most important variable overall, followed by Cost, and Delivery Performance.

Directions for future research

As in any empirical study we were faced with certain difficulties and limitations. Even though we have a multinational sample, the countries in our study were all in the same continent. We found some interesting differences across these cultures, and it would be very interesting to see whether these differences are even greater when different countries are sampled across continents. We also collected data in only one industry, so a possible extension could be to compare across industries. However, our approach seems to be the norm in this literature stream as we do not want the results to be diluted by sampling different industries.

As a final note to managers at suppliers, we would like to point out that the Value Added attributes used in this study seemed to be of small importance to the decision makers at the manufacturers, with the possible exception of engineering consulting (refer to Figure 3). We would therefore caution the suppliers against spending time and resources on these activities (providing risk and inventory management, and developing an online ordering support system for example), while the manufacturer is more interested in flexibility or a low price.

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Table 1: Supplier choice experiment: constructs, attributes and levels

Flexibility			**Value Added**		**Delivery Performance**	**Cost**
Production	*Demand*	*Variety*	*Support*	*Services*	*Speed*	
Experience with Alloy (2)	Rush orders (2)	Packaging type (2)	Risk Mgt (2)	Problem solving (4)	Prototype delivery (4)	Price (4)
Standards & Guidelines (2)	Small orders (2)	Packaging format (4)	Inventory Mgt (2)	Assembling services (3)	Lead Time (4)	
Manufacturing Tolerances (2)	Adj. annual demand (4)	Type of Products (4)	Engineering consulting (4)	Online ordering (3)	On time delivery (4)	
Machining Flexibility (3)	Proposal process (4)	Product ranges (3)	Order tracking (4)			

Note: numbers in brackets indicates levels for each experimental attribute.

Table 2: Sample Characteristics. Total sample size = 200.

Respondent's Country	
Germany	72.5%
United Kingdom	6.5%
Italy	9.0%
France	12.0%
Respondents' Job Function	
Purchasing Officer	54.5%
Plant Engineer	11.0%
Plant or Business Unit Manager	6.5%
Other (including no response)	28.0%
Industry	
Building component manufacturing	14.0%
Electronic equipment manufacturing	15.5%
Heating, AC, sanitary and renewable energy equipment manufacturing	3.0%
Household and office fixtures manufacturing	6.0%
Industrial machinery and equipment manufacturing	21.5%
Transportation equipment manufacturing	23.5%
Other	16.5%
Annual aluminum usage	
Less than 10 tons	26.5%
10 – 20 t	20.0%
21 – 50 t	8.0%
51 – 100 t	14.5%
101 – 1000 t	25.5%
More than 1000 t	5.5%

Table 3: The seven main effects for the three estimated supplier selection choice models in decreasing importance

Construct	Complete	Only German	Only Non-German (English, French, Italian)
Production Flexibility	1.6407	1.8763	1.0195
Value-added Support	1.4463	1.6178	0.9942
Variety Flexibility	1.3061	1.4621	0.8947
Delivery Performance	1.1628	1.2942	0.8165
Demand Flexibility	1.0564	1.1767	0.7393
Value-added Services	0.9478	1.1212	0.4905
Cost	**0.7265**	**0.6593**	**0.9037**

Figure 1: the flexibility constructs' main effects make up almost half of the total impact.

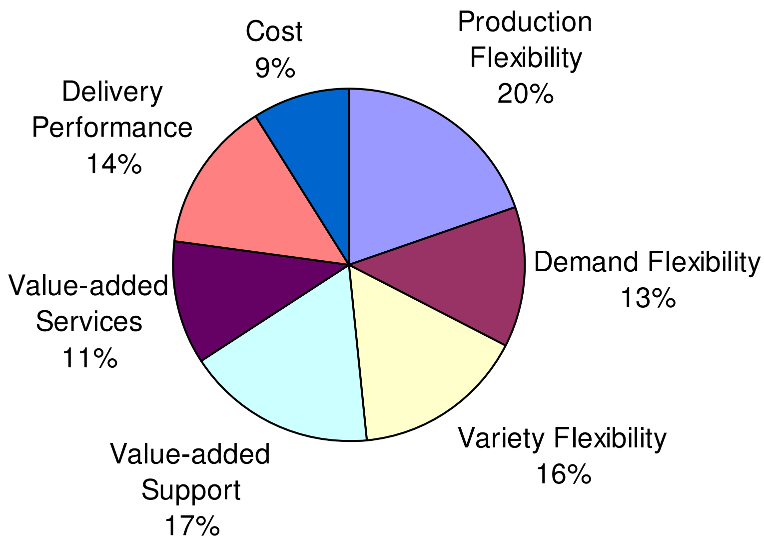

Figure 2: Comparing relative main effects of the attributes within the Production Flexibility, Value-Added Support and Services, and Cost subgroups

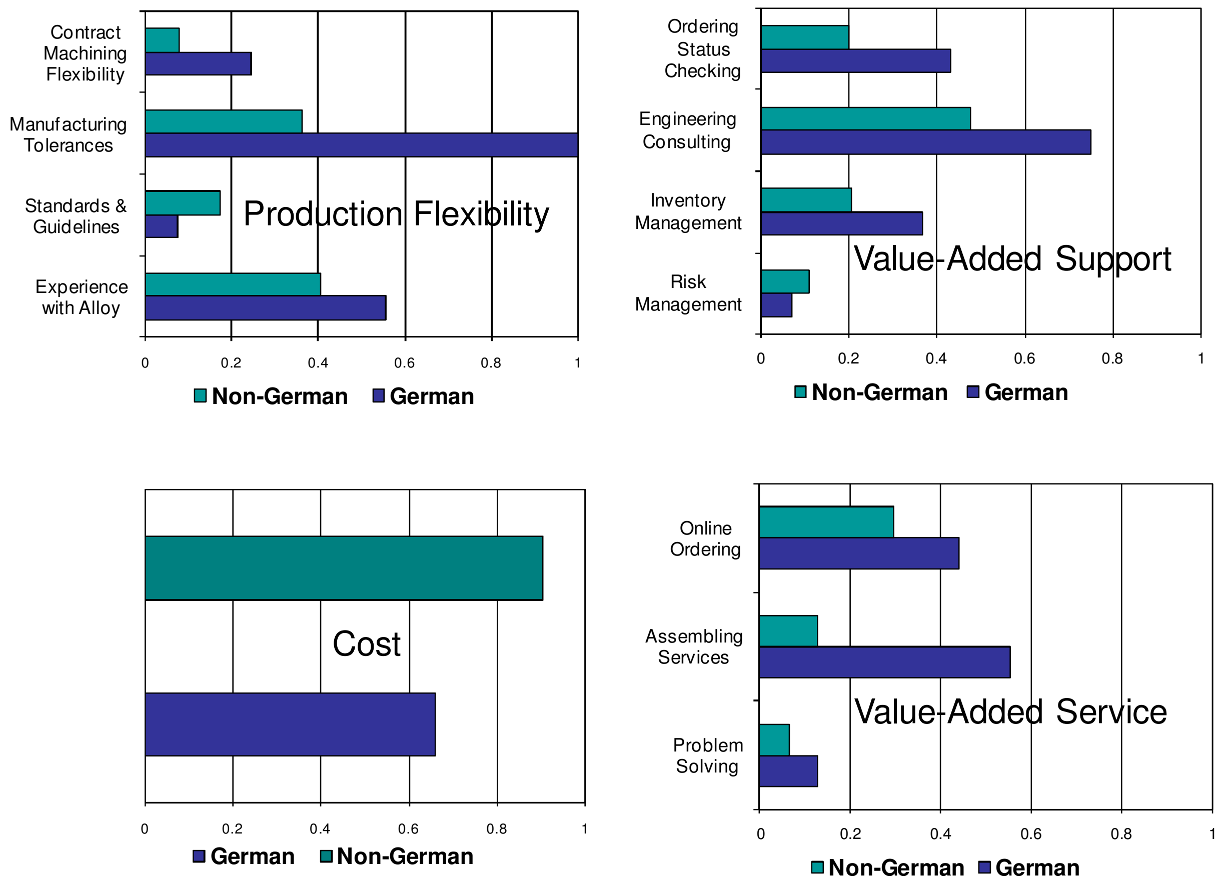

Figure 3: Relative main effects for the attributes in the complete selection choice model