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Understanding managerial preferences in selecting equipment

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Abstract

Industry continues to look for methods of gaining competitive advantage through manufacturing techniques. These techniques, however, can be matched by competitors if used without the guidance of a strategic framework. Similarly, structural capacity choices can be matched by competitors without the infrastructural benefits of a well defined operations strategy. In this study, multiattribute utility (MAU) theory analysis was used in an experiment to quantify the contribution of various structural and infrastructural strategic factors toward sustaining competitive advantage within the context of a capital equipment selection decision. The experimental respondents were manufacturing managers and professionals from the plastics industry. This research provides groundwork for understanding the role of strategic infrastructural factors in sustaining competitive advantage within the structural capacity decision of selecting capital equipment in the plastics industry.

Keywords: Capacity management; Empirical research; Measurement and methodology; Operations strategy; Multiattribute utility analysis

1. Introduction

An equipment purchasing decision impacts the capacity levels of a business (Persson, 1991). Oversized equipment selections can be costly in multiple ways including the initial outlay of cash and the subsequent result of having too much capacity (generating excessive inventories, idle equipment, etc.). Alternatively, undersizing equipment can result in greater penalties if lack of capacity constrains meeting customer demands (Markland et al., 1998). Equipment selection also has broader implications. For instance, the strategy adopted in selecting equipment can affect the flexibility of switching between products or ramping up products (Skinner, 1996).

Hayes (1985) argued that strategic infrastructural factors are the key to achieving competitive advantage. Skinner (1996) argued more specifically that strategic infrastructural factors in a capacity decision are an important source of competitive advantage. Capital investments have been viewed as strategic decisions (Lindberg et al., 1988; Persson, 1991). Capital equipment decisions based on engineering cost–benefit analysis considering productivity factors have deep roots in the industrial community (Sage, 1983; Newnan, 1991). However, if, as is hypothesized by Skinner (1996), the strategic considerations of these capacity decisions do represent sources of competitive advantage, then the acquisition of capital equipment provides an opportunity to gain sustainable competitive advantage.

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This paper details an experiment which measures the effect of various structural and infrastructural factors in a capital equipment selection decision. The capital equipment decision is made under experimental hypothetical conditions. The objective for this scenario is to use the purchase of equipment to gain a sustainable competitive advantage. The subjects were asked to select and purchase production equipment, which would help them meet the competitive priorities facing their assigned business.

The experiment is designed to evaluate how managers value structural and infrastructural factors in selecting equipment configurations to meet their assigned competitive priorities. The competitive priorities are unique to each treatment of this experiment, and the experiment limits the subjects' choices in equipment selection to four alternatives. The equipment choices are all of equal capacity. The subjects have the choice of purchasing one large machine, two medium large machines, four medium small machines or eight small machines to meet the demands of the hypothetical task presented to them. The equipment options are equal on all other attributes and priorities not considered as tradeoffs in the study. The subjects are all practicing managers or professionals in the polymer processing industry. The experiment is designed to capture their expertise at competing in this marketplace.

2. Background

A manufacturing strategy is defined by the total pattern of management decisions made across the manufacturing system not just in relation to the capital expenditures of 'brick and mortar', but it also includes systems and policies which define the infrastructure of a business (Clark, 1996). Therefore, a manufacturing firm's strategy will guide the decisions on each of the priorities in which the firm chooses to compete. In addition, some (Hayes and Wheelwright, 1984; Skinner, 1996) have argued that attaining sustainable competitive advantage cannot be achieved without including infrastructural considerations in such decisions as equipment selection choices.

Skinner has proposed the use of manufacturing strategy to gain sustainable competitive advantage since 1969 (Skinner, 1969). Others continue to study this problem (e.g. Leong et al., 1990; Mills et al., 1995). The industrial community looks for methods of gaining competitive advantage through manufacturing techniques like just-in-time or quality improvement programs (De Meyer et al., 1989). Skinner (1996) has recently warned against the pitfalls of using these techniques (referred to collectively as advanced manufacturing techniques or AMTs) without using an operations and/or business strategy as a guiding vehicle. Skinner points out that using competitive priorities does not necessarily mean a strategic framework is used. Some researchers (Ferdows and De Meyer, 1990) have offered ideas about how to use AMTs in strategic initiatives. Without a strategic framework, any competitive advantage that may be obtained ultimately can be lost.

Skinner (1996) recommends a framework of strategic design considerations. He lists six areas of strategic design: (1) vertical integration, (2) level of capacity, (3) equipment and process choice, (4) facility numbers, location, and sizes, (5) infrastructure decisions, and (6) management techniques. These six areas overlap Hayes and Wheelwright's (Hayes and Wheelwright, 1984) eight decision areas of manufacturing strategy. Hayes and Wheelwright's list is as follows: capacity, facility, technology, vertical integration, workforce, quality, production planning, and organization. Skinner (1996) lists 35 AMTs, so as a matter of perspective, if a company chooses to compete on any one or two, like JIT, TQM, or re-engineering, then that company is limiting itself within Skinner's strategic framework. Of the six strategic design categories, Skinner (1996) states that capacity levels and equipment/process choices are probably two of the most understudied areas in this field. Tracey et al. (1999) argue that investing in advanced manufacturing technology and facilitating manufacturing managers in strategy formulation improve competitive capability.

The strategic priorities on which manufacturing firms choose to compete are referred to as competitive priorities (Schmenner, 1984; Fine and Hax, 1985; Hayes, 1985; Skinner, 1985). Competitive priorities in manufacturing can include cost, innovation, quality, delivery performance (dependability and speed), flexibility, and rapid new product introduction (Vickery, 1991; Ward et al., 1998). These competitive priorities are consistent with the dimensions that qualify a firm to be a supplier for a customer, or an ‘order qualifier’, and subsequently to be chosen as the supplier of choice by a customer, or an ‘order winner’ (Hill, 1989). These strategic competitive priorities are used to establish the basis of this experiment.

This study specifically examines infrastructural and structural factors to ascertain their contribution towards attaining sustained competitive advantage under various competitive scenarios. While many individual factors of both types influence an equipment selection decision, 10 are selected for investigation based on literature precedent and the results of a pilot study. Five factors are included under the general heading of structural factors and five are included under the general heading of infrastructural factors. The five engineering cost–benefit or structural factors are productivity, reduced processing time, initial investment, operating cost, and automation potential (Tarquin and Blank, 1976; Fine and Hax, 1985; Lefley, 1996). The five infrastructural factors include operator knowledge and learning, setups, professional/engineering skills, teamwork, and managerial skills (Fine and Hax, 1985; Hayes et al., 1988; Mata et al., 1995; Upton, 1995).

3. The decision

In as early as 1975, Wild (1975) proposed an equipment selection procedure which involved breaking the decision into quantifiable and non-quantifiable factors. Quantifiable costs included traditional equipment cost justification considerations like the price of the capital equipment purchase, setup costs, space requirements, and inventory requirements. Wild (1975) considered non-quantifiable cost factors to include such factors as human resource staffing, working conditions and automation integration. Since then others (Sage, 1983; Ancel and Griffiths, 1996; Lefley, 1996) continue to support the position of including infrastructural factors in the equipment purchase decision.

While engineering cost justification equipment analysis has evolved somewhat to include infrastructural considerations, traditional cost engineering priorities remain technically oriented (Newnan, 1991). It is not that practitioners buy equipment in a random fashion without accounting for the strategies of their companies. Instead, manufacturers in many cases subscribe to traditional thinking that equipment needs to be purchased through cost justification procedures (Noaker, 1994). Traditional cost justification methods include accounting rate of return methods (e.g. return on investment), discounted cash flows, or simple payback methods. These methods are based on narrowly focused traditional cost justification methods which remain universally applied through improved productivity targets regardless of operating strategies (Noaker, 1994). Despite a calling for expanding criteria in justifying equipment to include strategic aspects of their companies, practicing managers continue to justify equipment through cost justification packages (Noaker, 1994).

Using equipment purchase alternatives as choices in managerial decision models is not without precedent. Kalotay (1973) used the choice of machine types as a model for capacity expansion under various demand patterns. Karmarkar and Kekre (1987) used machine size and number options to study product mix and capacity decisions. Van der Veen and Jordan (1989) used the machine purchase alternatives to examine trade-offs between machine investment and utilization decisions. In each of these cases, equipment alternatives were systematically used to examine effects of economically sensitive managerial operating decisions.

4. Experimental methodology

The nature of this experiment lends itself to using multiattribute utility (MAU) models. Multiattribute utility decision making models can be built to measure a decision maker’s view of opportunity costs associated with factors outside of financial cost–benefit analysis (Keeney and Raiffa, 1976). Since exploring the limits of the efficient frontier involves exploring criteria not always measured on the same dimension (e.g. risk versus return on the financial portfolio efficient frontier curve, see Van Horne (1988)), one economic method of modeling the frontier is with a utility scale (Keeney and Raiffa, 1976). The advantage that a MAU model provides is that it transforms multiple criteria, not normally compared due to incompatible scales, onto value utility scales which can be compared and analyzed. By using MAU analysis, differences in the value of factors influenced by a manufacturing strategic decision can be explored.

MAU models have a specific advantage in this case because of the difficulty of using non-traditional or non-cost related measures of value for justifications in purchasing capital equipment. A field experiment of operations managers using hypothetical scenario analysis can provide an opportunity to explore strategic considerations in the equipment decision because of their expertise and knowledge of this particular marketplace (the polymer processing industry). Measuring the experts' evaluation of the utility of these infrastructural factors is an important advantage of MAU analysis (Keeney and Raiffa, 1976). In general, a field experiment defines factors which may not be included in a mathematical model, and it measures changes caused by effects which a survey does not usually directly capture. Both, determining the important factors and measuring the effect of the factors, contribute towards understanding the value of attaining competitive advantage at least specific to this decision.

Multiattribute utility theory and the model of this research follow Olson (1996) where the framework of the theory follows the linear weighting rule model of Keeney and Raiffa (1976).

$$v(x_j) = \sum w_i(x_j)$$

where w_i is the relative weight of criterion i and x_j is the scaled value alternative j has on criterion i. Both the weight and the scaled value alternative were presented to the respondents on 0–10 scales to enhance respondent understanding. These numbers were scaled back to 0–1 scales by dividing responses by 10 facilitating identification with MAU methodology (Olson, 1996). The scaled response scoring sheets are attached in Appendices A and B.

The method of research is a designed experiment using multiattribute utility analysis. A designed experiment typically involves subjecting samples to separate levels of treatments then measuring the intended effect. The effect, in this research, is achieving sustained competitive advantage. Sustained competitive advantage can be thought of as sustaining greater than industry average profitability (Hitt et al., 1995). Future research can extend this investigation to beyond the subset of Skinner (1996) six areas being considered in this research (capacity, equipment choice, and infrastructure). The controlled experiment in this research focuses on perceived importance of these specific factors on equipment choice utilizing MAU analysis.

4.1. The pilot

Many possible experimental scenarios involving strategic competitive priorities, alternatives, and attributes are identified in the literature. Vickery (1991), for example, summarized the strategic competitive priorities to include cost, product/process innovation, quality, delivery performance, flexibility (mix and volume), and rapid new product development. Van der Veen and Jordan (1989) examined the effect of the investment decision on utilization when making machine sizing decisions. Lefley (1996) argued that a number of both traditional cost–benefit measures and infrastructural attributes should be considered important in this decision. Therefore, an experimental design in this area could be prohibitively large and potentially confounding.

A pilot study was used to identify a filtered list of alternatives, attributes, scenarios, and questions used in this study. The pilot study and the experiment are not intended to be conclusively final in identifying strategic priorities in the equipment decision, but rather these were intended to provide a starting point for the investigation. The pilot subjects were colleagues, friends in the plastics industry, and mentors whose opinions were respected for various points of expertise and honest feedback. The testing forms and definitions were allowed to adjust, change, and evolve because the main concern of the pilot study was to achieve clarity, efficiency, and solidify working definitions that were representative of both industry and academia. A sampling of the working definitions of market strategy, product development strategy, and customer services strategy are included in Appendix A. An example of the attribute definition anchors are included in Appendix B.

The pilot was helpful in identifying one possible combination of competitive priorities to form experimental scenarios. Many combinations and scenarios are possible, all representing extensions of this research. The combinations established for this experiment are not intended to imply that a preconceived relationship exists between these priorities and scenarios. Instead, alternative combinations could lead to new discoveries on this experimental horizon.

4.2. The experiment

The experiment uses MAU theory to gain insight into subject expertise. The process is as follows. The subjects, who are managers from one selected industry (the plastic processing industry), were each assigned to one of the eight treatments. The treatments were built from aspects of manufacturing competitive priorities (Vickery, 1991), aspects of Porter's cost leadership and product differentiation determinants (Porter, 1985) and aspects of Hill's order winning criteria (Hill, 1989). The subjects were given four alternatives of machine choice from which to select.

Of the alternatives presented to the subjects, none by design offered a clear competitive advantage over the other on any of the given dimensions. For example as described in the appendices, the alternatives consisted of one large machine, two medium large machines, four medium small machines, or eight small machines all directly scaleable (e.g. one 400 t machine, two 200 t machines, four 100 t machines, or eight 50 t machines). The manager (subject) was left to achieve competitive advantage by strategically using the alternative to best meet the experimental scenario. For example, one large machine is faster and more productive than one 50 t machine, but it is not faster and more productive than eight 50 t machines working together. Therefore, given a scenario of making several products, would it be strategically better to make several products one at a time on a big fast machine (incurring set ups, inventory build up, etc.) or would it be better to dedicate lines to certain products on smaller machines (lowering productivity, etc.)? Residual questions managers had to consider in view of their priorities included for instance what would be the strategic implications in terms of quality, deliverability, flexibility, etc. given their alternatives and which of the alternatives would best meet their given priorities?

The subjects were asked to select an alternative that provided them with, in their expert opinion, the equipment choice most likely to sustain competitive advantage. In doing this, they were asked to provide both their preferences for factors (engineering cost–benefit factors and infrastructural factors) and weights of importance which they assigned to the factors in making their capacity selections. MAU analysis techniques were used to aggregate the factor weights and preferential value of the factors toward achieving sustained competitive advantage (Olson, 1996). The aggregated results of the factor weights going into the capacity choices and the capacity level selections were compared between treatments to understand differences in choices between treatments in achieving competitive advantage.

Three factors, each having two levels (a $2\times2\times2$ design), were under consideration in this experiment. The factor levels of the experiment are also referred to as the competitive priorities because when a subject was placed in a treatment, he was presented with a description of the respective hypothetical competitive scenario. The subjects were told that in their hypothetical manufacturing scenario the executive to which they report has dictated that they are competing on three primary priorities, all of equal weighting. These three competitive priorities (of two levels each) are the three factors of the experiment.

The three competitive priorities represent differentiation strategies within a manufacturing operation. The first factor is referred to as a market differentiation strategy. Under this strategy, the firm may be competing by being a lower cost producer, or the firm may be competing with product differentiation. While many other marketing strategies exist, the experiment was controlled by presenting these limited extremes.

The second factor is referred to as a new product development strategy. Under this priority, the firm may have a rapid new product development priority or a product continuous improvement priority. The new product development priority forces a manufacturing operation to allocate production time to develop products quickly. The description for this strategy includes a statement that profit is made by a market introduction that is quicker than the competition. After the introduction, competition quickly matches the product at which time above average profit margins are lost. The task of the continuous improvement priority is to continually improve the quality of an existing product.

The third experimental factor is referred to as a customer service strategy. Under this priority, the two priorities are delivery reliability and flexibility. If delivery reliability is the priority, then production schedules are set. Changes to the production schedule are not allowed, and promised dates are important. The second customer service priority is flexibility. If flexibility is the priority, then quick changeovers are emphasized and reacting to customer changes is the important consideration.

In summary, the three competitive priorities or factors in this experiment are as follows: a market differentiation priority, a new product development priority, and a customer service priority. Each factor has two priorities. The two priorities of the market differentiation priority are low cost and product uniqueness. The two priorities of the new product development priority are rapid new product development and continuous product improvement. The two priorities of customer service are delivery reliability and flexibility.

The treatments represent a combination of the priorities of all three factors (Lentner and Bishop, 1993). In a $2\times2\times2$ design, eight total treatments are designed in the complete combination of factor priorities. The respondents are given a scenario in which the combination of levels represents the competitive priorities of that treatment. The combinations of priorities along with an *x*-, *y*- and *z*-axis three-dimensional coding scheme are presented in Table 1.

If the codes are plotted on a three-dimensional graph, the axes of the graph can be labeled with each of the associated priorities. The resulting configuration of the design can be thought of as a cube. Each corner of the cube represents a treatment. Fig. 1 is a diagram of the configuration of the combined levels of the designed experiment.

Each corner point in Fig. 1 represents a treatment. Every subject participating in the study was placed in one of the treatments. Any treatment can be referred

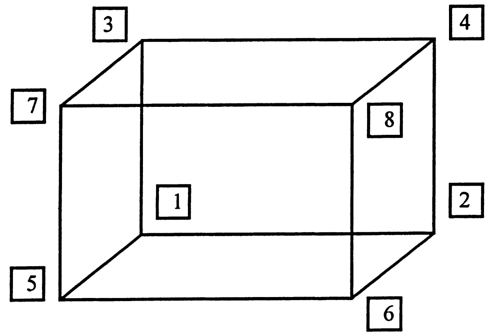

Fig. 1. Configuration of the treatments of the designed experiment.

to through its number or its coding scheme. For instance treatment 6 is also treatment (+1, −1, +1) on the (*x*-, *y*-, *z*-axis) coding scheme. This means that any person participating in the study assigned to treatment 6 is given the hypothetical manufacturing scenario having the competitive priorities of maintaining unique products in the marketplace, developing new products rapidly, and meeting promised delivery dates. The treatments, in this way, represent combining the factor levels (Table 1).

5. The hypotheses

Four hypotheses are tested in this experiment. Each evaluates the effects of the competitive priority treatments on each of the capacity alternatives. A separate hypothesis is tested for each alternative: one large machine, two medium large machines, four medium small machines and eight small machines. Each of these hypotheses formally stated is as follows.

Table 1
Coding scheme of the designed experiment

Treatment	*x*-axis	*y*-axis	*z*-axis	Priority description
1	−1	−1	−1	Competes on cost, product development, and flexibility priorities
2	+1	−1	−1	Competes on unique product, product development, and flexibility priorities
3	−1	+1	−1	Competes on cost, quality, and flexibility priorities
4	+1	+1	−1	Competes on unique product, quality, and flexibility priorities
5	−1	−1	+1	Competes on cost, product development, and delivery reliability
6	+1	−1	+1	Competes on unique product, product development, and delivery reliability
7	−1	+1	+1	Competes on cost, quality, and delivery reliability priorities
8	+1	+1	+1	Competes on unique product, quality, and delivery reliability priorities

Hypothesis 1. The choice of one large machine is not affected by different manufacturing priorities used by managers attempting to gain competitive advantage.

Hypothesis 2. The choice of two medium large machines is not affected by different manufacturing priorities used by managers attempting to gain competitive advantage.

Hypothesis 3. The choice of four medium small machines is not affected by different manufacturing priorities used by managers attempting to gain competitive advantage.

Hypothesis 4. The choice of eight small machines is not affected by different manufacturing priorities used by managers attempting to gain competitive advantage.

The experiment tests each hypothesis by considering how managerial preferences change under different scenarios (treatments of the designed experiment) of manufacturing competitive priority. All the subjects are instructed to use the equipment decision to gain sustainable competitive advantage, so by changing the scenario of manufacturing priority, the factors can be evaluated for degree of change. These responses are tested for significance between alternatives. For each of the hypotheses, the responses from the MAU analysis will be used to reject, or fail to reject, the hypotheses.

6. A profile of the respondents

The data was collected by the recruitment of managers and professionals to participate in the study. The managers and professionals all were from plastics and allied industries. The subjects were recruited at five separate industry conferences. Since 104 subjects participated, the experiment was able to carry 13 sets of subjects in each treatment. The experiment was controlled for balance by placing a subject in all eight treatments prior to proceeding to the next set of subjects.

The participants were from a variety of functional positions. The participants were all required to have a professional or managerial position, and they had to have had some degree of experience in the operations area. The profile of the participants is in Fig. 2.

The participants were classified into one of the categories seen in Fig. 2. Anybody who was a top-level executive was assigned to the first position. A top-level executive was defined as someone having multifunctional responsibilities. The people qualifying for this designation included presidents, CEOs, vice-presidents, business directors, or general managers; 31 of the 104 participants or approximately 30% or the respondents had one of these job designations. The next two main areas of designation included functional managers (column 2) and professionals (column 3) who were not currently in operations related positions. Professionals were defined as engineers or technical people. Some of these participants

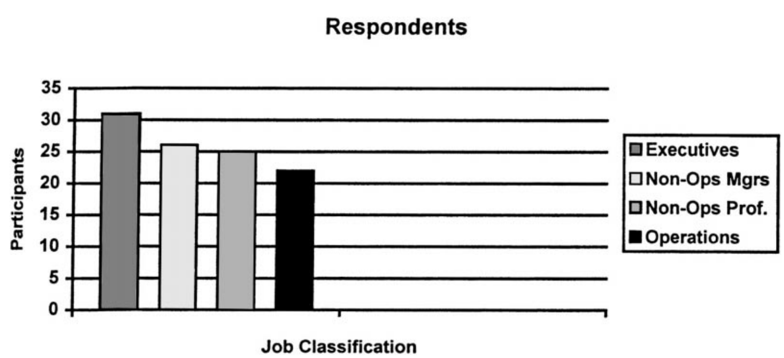

Fig. 2. Backgrounds of the participants.

reported directly to the operations function others reported through a technical function. The manager and professional categories had 26 managers (25% of the participants) and 25 professionals (24% of the participants), respectively. The last designation for participants included anyone with direct functional responsibility in the operations area. The people qualifying for this designation were plant managers, operations managers, and process or production related engineers. A total of 22 of these professionals or approximately 21% of these subjects participated in the study.

The respondents came from different companies. This was a requirement of the experiment in maintaining independence between subjects. Therefore, just as there were 104 different subjects, there were also 104 different companies. The companies ranged in size from small companies to large multi-national companies. Some of the recognizable names of the companies of some of the participants included Amoco, Chevron, DeWalt, Union Camp, Dupont, Eastman, Avery, 3M, NCR, Bridgestone, Olin, Bayer, Dow, Rohm and Haas, and Borg-Warner.

In summary, the respondents were from a variety of functional, managerial, and professional responsibilities in the plastics industry. The respondents were from a variety of geographical locations. The respondents were from five different professional business conferences that target different audiences in the industry. Each of these points helped to assure a diversification of the responses, and should therefore, minimize data bias from geographical, cultural, or corporate influences. Independence of the data is improved by preventing subjects from the same company from participating. If subjects from the same company had participated, the influence of a company's business beliefs and practices may contribute bias to the responses. By limiting participation to one respondent per company, company influences are minimized. A generalization of the results to the industry as a whole, therefore, is improved through the diversification of the respondents.

7. Results

Each of the subjects gave responses to questions under the different scenarios that were presented to them. The respondents were asked to rank the attributes and rate the alternatives on each attribute. The MAU result was calculated from these responses. The MAU results of all the respondents were then aggregated by treatment. The results of these calculations showed that multiple machine options were generally preferred over the single machine alternative as a strategic option. While in some cases the single machine option was not statistically less preferred than multiple machine alternatives, this option was the preferred choice in some treatments. Further analysis may help to understand this result, but first the full preference matrix can be seen in Table 2.

The values in Table 2 are MAU preference values on a 0–1 scale, so the higher the number the more that option is preferred in that particular treatment. Tests for significance were run on the results from all four machine alternative preferential values. One-way analysis of variance (ANOVA) testing was used to determine significance. The results of the ANOVA are below in Table 3.

The ANOVA results for the single machine MAU response show that none of the effects are significant at the $\alpha=0.05$ level. The preference for the single machine alternative has a weak effect ($0.10\leq\alpha<0.05$) from the market differentiation (MD) main factor. The ANOVA results for the two machine MAU response show that the main effect of the *x*-axis or the MD strategy is significant at the $\alpha=0.05$ level. This indicates that this factor is significant in affecting manager's preferences for two machines.

The ANOVA results for the four machine MAU response show that the main effect of the *x*-axis or the MD strategy is weakly significant at the $\alpha=0.10$ level. The interaction between the market differentiation strategy and the product development (PD) strategy is significant at the $\alpha=0.05$ level ($p=0.0189$). The ANOVA results for the eight machine MAU response show that the interaction of the MD strategy and the product development strategy is significant at the $\alpha=0.05$ level. Specifically the *p*-value of the interaction is $p=0.0256$. The MD main factor is also weakly significant. A summary of these effects is presented in Table 4. The market differentiation by product development interaction indicates that managers value multiple machine capability when producing unique products while they are also developing new products.

Table 2
MAU preference results by treatment

Treatment	Responses	Measures	One machine	Two machines	Four machines	Eight machines
1	13	Average	0.352	0.446	0.540	0.478
		S.D.	0.101	0.118	0.127	0.168
2	13	Average	0.393	0.444	0.493	0.475
		S.D.	0.122	0.103	0.127	0.165
3	13	Average	0.409	0.442	0.421	0.352
		S.D.	0.128	0.094	0.080	0.113
4	13	Average	0.408	0.481	0.514	0.444
		S.D.	0.146	0.124	0.122	0.134
5	13	Average	0.389	0.444	0.481	0.430
		S.D.	0.152	0.113	0.102	0.118
6	13	Average	0.481	0.544	0.499	0.405
		S.D.	0.195	0.155	0.148	0.192
7	13	Average	0.381	0.439	0.426	0.345
		S.D.	0.095	0.093	0.087	0.119
8	13	Average	0.466	0.508	0.524	0.483
		S.D.	0.168	0.150	0.132	0.123

Table 3
ANOVA results

Source	d.f.	Alternative 1, *p*-values	Alternative 2, *p*-values	Alternative 4, *p*-values	Alternative 8, *p*-values
Model	7	0.3029	0.2328	0.1016*	0.0808*
MD	1	0.0543**	0.0321**	0.0794*	0.0779*
PD	1	0.6572	0.9328	0.1724	0.1522
MD×PD	1	0.6626	0.9171	0.0189**	0.0256**
CS	1	0.1645	0.2006	0.6771	0.4523
MD×CS	1	0.2189	0.1697	0.4596	0.8266
PD×CS	1	0.3982	0.4411	0.4652	0.1852
MD×PD×CS	1	0.7589	0.4512	0.5249	0.5430

* $p \leq 0.10$.
** $p \leq 0.05$.

Table 4
Summary of experimental effects on the MAU preference values

Alternative	Experimental factor	Treatment priority with the highest preference value
One large machine	MD (weak)	Unique products
Two medium–large machines	MD	Unique products
Four medium–small machines	MD×PD	Unique products and new product development
	MD (weak)	Unique products
Eight small machines	MD×PD	Unique products and new product development
	MD (weak)	Unique products

As can be seen from Table 4, the preference for using multiple machines (four and eight machines) on which to compete increases under new product development competitive priorities. This effect is weak at the α=0.10 level. The result is not surprising because these capacity alternatives offer parallel processing options for the managers. The result, which was unexpected, was the fewer (one and two) machine alternative results.

The alternatives with fewer (one and two) machines show a tendency to have preference values increase in treatments competing with unique products. In the case of the single machine alternative, this effect is a weak (at the α=0.10 level) effect, but in the case of the two-machine alternative, this effect is significant at the α=0.05 level. Further *t*-test analysis for paired comparisons between alternatives within treatments was used to explain this result because this procedure helps identify which alternatives are preferred under the various priorities.

The procedure uses paired *t*-tests to compare MAU values within treatments. In this way the MAU values are tested for significant differences. This information helps explain which alternatives if any are preferred over others in different treatments. The *p*-values are better understood when the alternatives from Table 2 are reordered by MAU value. The reordered values (highest to lowest) by treatment are in Table 5.

Table 5
Ordered alternatives by MAU preference values

Treatment	Ordered (highest to lowest) alternatives
1	4, 8, 2, 1
2	4, 8, 2, 1
3	2, 4, 1, 8
4	4, 2, 8, 1
5	4, 2, 8, 1
6	2, 4, 1, 8
7	2, 4, 1, 8
8	4, 2, 8, 1

The *t*-test *p*-values were then used to determine if these alternatives were significantly different within each treatment. The *p*-value results of the *t*-tests are presented in Table 6. As can be seen in treatment 1, there is not a statistical difference between alternatives four and eight or eight and two. This means only alternative one is different. Table 6 is presented below.

Table 6
The *p*-value results of MAU alternative differences by treatment

	Machine alternatives				Machine alternatives		
	2	4	8		2	4	8
Treatment 1				*Treatment* 5			
1	0.040**	0.0004**	0.030**	1	0.305	0.083*	0.452
2	–	0.065*	0.583	2	–	0.393	0.754
4	–	–	0.303	4	–	–	0.249
Treatment 2				*Treatment* 6			
1	0.256	0.050**	0.161	1	0.372	0.800	0.325
2	–	0.292	0.675	2	–	0.452	0.053*
4	–	–	0.756	4	–	–	0.177
Treatment 3				*Treatment* 7			
1	0.461	0.781	0.245	1	0.128	0.226	0.402
2	–	0.542	0.038**	2	–	0.701	0.034**
4	–	–	0.087*	4	–	–	0.061*
Treatment 4				*Treatment* 8			
1	0.182	0.056*	0.525	1	0.509	0.338	0.771
2	–	0.496	0.463	2	–	0.776	0.648
4	–	–	0.170	4	–	–	0.423

* $p \leq 0.10$.
** $p \leq 0.05$.

Table 7
Effect of the treatment priorities on alternatives

Strategic priority	Cost	Unique products	Quality	New product development	Flexibility	Delivery reliability
Treatment 1	4, 8			4, 8	4, 8	
Treatment 2		2, 4, 8		2, 4, 8	2, 4, 8	
Treatment 3	1, 2, 4		1, 2, 4		1, 2, 4	
Treatment 4		2, 4, 8	2, 4, 8		2, 4, 8	
Treatment 5	2, 4, 8			2, 4, 8		2, 4, 8
Treatment 6		1, 2, 4		1, 2, 4		1, 2, 4
Treatment 7	1, 2, 4		1, 2, 4			1, 2, 4
Treatment 8		1, 2, 4, 8	1, 2, 4, 8			1, 2, 4, 8
Effect[a]	1 and 8 eliminated	1 eliminated	8 eliminated	1 eliminated	1 eliminated	8 eliminated

[a] The alternative was considered eliminated through a heuristic which determined that unless the alternative was statistically significant in at least three of the four treatments containing that priority then the alternative was eliminated.

The results indicated that in all but one treatment the most preferred and the least preferred alternatives were statistically different (at an α=0.10 level). The other alternatives were not statistically different. Therefore, as an example in treatment 1, alternative four cannot be selected as the preferred alternative because it is not significantly preferred over alternatives eight or two. If, however, alternative one is considered eliminated based on statistical differences, then an interesting dynamic develops. This dynamic is presented in Table 7.

In Table 7, the machine alternatives which were measured as at least weakly significant (to the α=0.10 level) are listed by treatment under each priority. For instance, treatment 2 presents a respondent with the challenge of competing with three specific strategic priorities (unique products, developing new products, and flexibility) shows that the respondents preferred to eliminate the one large machine alternative and preferred to compete on these priorities with multiple machine alternatives. The columns, then, represent each of the treatments the priority was presented to the respondents. The priority of competing with unique products was presented to the respondents assigned to treatments 2, 4, 6 and 8. When the column was examined, the machine alternatives, which were not preferred in at least three of four treatments, were then eliminated to emphasize priority tendencies.

The summarized results in the last row of Table 7 showed that managers competing on unique product, new product development, and flexibility priorities tended to eliminate the one large machine alternative. Those competing on delivery reliability and quality priorities tended to not select the eight smaller machines. Those competing on cost priorities preferred to compete with the two and four alternatives. It is this particular result that provides insight into the ANOVA results for the fewer (one and two) machine alternatives in Table 4. These results indicate that under cost priorities managers tended to favor the middle alternatives (two and four machines) avoiding in particular the large single machine alternative.

8. Discussion and conclusions

Based on the ANOVA results, the conclusion that operating strategies affect capacity choices was supported. Under the boundaries of this study, when managers were given a strategic priority, they endeavored to use those capacity choices to meet the strategic goals. Even in the case of the single machine alternative, the experimental factors influenced how this alternative was viewed. Infrastructural factors were valued in using this option with which to compete. This was understandable because a single machine limits the number of degrees of freedom a manager has in operating. Therefore, other intangible factors must be utilized to support the use of this capacity choice.

The respondents in this experiment preferred in all eight treatments to operate with multiple machines.

The objective assigned to the respondents was to gain and sustain competitive advantage by purchasing one of the equipment choices. The choices were scalable and equal. Therefore, each alternative resulted in an option, which could help them meet the strategic goals of their assigned treatment. In some of the treatments, an a priori expectation would be that the managers and professionals would use big, fast, and productive equipment to gain advantages through such structural factors as reducing costs and increasing productivity. Despite existing theory regarding these structural influences, the respondents chose alternatives that resulted in managerial options for them. Even when cost is a priority, managers appear to consider reliability in making decisions.

The evidence indicated that structural considerations may have influenced managers' values under quality and delivery priorities. The effect from these two priorities was that respondents tended to preferentially eliminate the eight small machine alternative as an operating option (Table 7). Therefore, the evidence supports the conclusions that quality and delivery priorities favored fewer machine alternatives. Preferring fewer larger machines would be logical if machine-to-machine variability was a quality concern. This would occur when the same product was produced on different machines introducing unwanted variability in the product. Preferring fewer larger machines would be logical under delivery priorities if managers perceived that the parallel processing machines would be loaded out with other scheduled products.

The evidence indicated that the priorities of unique products, new product development and flexibility either individually or through interactions tended to eliminate the respondents' preferences for fewer (one) machines (Table 7). The respondents valued multiple machines (two under the unique product priority and four or eight under interacting priorities of competing with unique products and developing new products). Therefore, the conclusion was supported statistically, despite the presence of experimental noise limiting statistical significance, that subjects competing on these priorities tended to have higher preferences for the multiple machine alternatives. The multiple machine alternatives provided the respondents with managerial options in meeting the customer demands of these priorities. The respondents' preferences, however, for one machine were uniquely explained by evaluating the results from the cost priorities.

Cost priorities had the effect of eliminating both the one and eight machine alternatives. The results in Table 7 showed that when faced with cost priorities, respondents tended to eliminate the one large machine option and the eight small machine alternative. This was the only priority that eliminated these two alternatives. One possible alternative of this experiment was that the subjects would meet this challenge of lowering costs by buying the biggest, most productive machine as a means to cut as many costs as possible. The results, however, were contradictory to this reasoning. Managers wanted the reliability of a second machine. If one machine went down for maintenance, then at least a second machine was available for production. The results supported the reliability argument indicating that, while cost driven structural factors are important to manage, the subjects would approach the cost differentiation strategy with the reliability of two or four machines.

The ANOVA results support rejecting the hypotheses. Operating strategy, as expressed by competitive priorities, has a significant effect on equipment choice. The different strategic priorities generated different solutions (Table 7). In all cases, the extremes (though not necessarily both extremes) were eliminated. This is perhaps expected, but moving towards the mean would have been easier to explain if both extremes were eliminated. Removing the eight machine alternative, however, signifies a preference for fewer machines while removing the one machine alternative signifies a preference for multiple machines. This means that the managers were endeavoring to use the equipment selection decision to meet the managerial priorities presented to them.

This research can be extended through the investigation of additional capacity choices, additional design areas, or other experimental priorities. Skinner (1996) argues that research for gaining and sustaining a competitive advantage is needed in other areas including assets, resources, and the employment of those resources. The extensions of this research involve investigating assets and resources including other types of manufacturing equipment, other assets like computing equipment, building space, or even operating personnel. This line of research then can be used to investigate application to other businesses. For instance, the research can investigate how banks should strategically use capacity resources to gain and sustain competitive advantage or how hospitals can utilize assets to gain and sustain a strategic competitive advantage.

Appendix A

A.1. Experiment scenario

You are making a decision to purchase equipment. You are hoping to gain sustainable competitive advantage over your competitors by purchasing this equipment.

You are going to randomly be put into a manufacturing scenario which will give you additional information. In this scenario, you will be given three manufacturing priorities on which you are competing in the marketplace. It is important that you give all three priorities equal weighting even if they appear to be competing priorities. Your ability to reconcile and achieve all three priorities will provide significant information in this study.

You are going to buy the equipment to fit the scenario presented to you. You are trying to decide between purchasing among the following options:

- one large machine (e.g. one 400 t machine);
- two larger medium sized machines (e.g. two 200 t machines);
- four smaller medium sized machines (e.g. four 100 t machines);
- eight small machines (e.g. eight 50 t machines).

Each of the purchase options are capable of running the jobs with relative capability, equal productivity, quality, etc. For example, the eight smaller machines taken together can produce equal pounds in an hour which one large machine can produce.

With this equipment purchase, your current plan is to produce approximately 16 commercial grade products. You can meet the demand of all 16 products on any of the four machine options, but by running all 16 products about 80% of your machine time will be utilized including both run time and setup time for these products.

A.2. Example scenario 1

- You need to sustain competitive advantage over your competitors.
- You need to make an equipment purchase to handle 16 commercial products.
- This will require 80% of your machine time.
- You need to differentiate yourself on three competitive priorities.
- Equal weight is assigned to all three competing priorities. These three strategic priorities for you are as follows:
  1. *Market strategy*: You are a cost differentiator. Your company competes by driving cost lower.
  2. *Product development strategy*: You develop new products rapidly for your customers. This is a selling point of your operation.
  3. *Customer services strategy*: Flexibility is paramount. You need to be able to switch between products quickly.

A.3. Example scenario 2

- You need to sustain competitive advantage over your competitors.
- You need to make an equipment purchase to handle 16 commercial products.
- This will require 80% of your machine time.
- You need to differentiate yourself on three competitive priorities.
- Equal weight is assigned to all three competing priorities. These three strategic priorities for you are as follows:
  1. *Market strategy*: You are a product differentiator. Your company competes by providing a unique product to the marketplace.
  2. *Product development strategy*: You continuously improve the quality of your existing product lines. This is a selling point of your company.
  3. *Customer services strategy*: Delivery reliability is paramount. You need to be able to promise a delivery date, schedule the products to be made, and then make that delivery date as promised.

Appendix B Alternative ranking across attributes

Your scenario number is _______.

On a scale of 10 to 1, please rate each equipment alternative for how it would perform in achieving the effect of the factor. Please score each alternative on where it falls on the relative scale provided. Ties are allowed. Please note that this exercise may be independent of your competitive priorities, but please remember that the equipment is 80% loaded with 16 commercial products and some level of product development may be needed. Hint: It is easier to think about this one line item at a time.

Example:	1 Lg	2 M-Lg	4 M-Sm	8 Sm	(Logic: Spare part commonality makes it
Maintenance	4	10	8	6	easier to keep multiple machines running.)

	1 Lg Mach.	2 Med-Lg Mach	4 Med-Sm Mach	8 Small Mach
Initial Investment (Where 10 is $500,000 and 1 is 850,000.)	_____	_____	_____	_____
Fast Setups (Where 10 is a %50 reduction achieved and 1 is little or no reduction achieved.)	_____	_____	_____	_____
Overall Operating Costs (Where 10 is $5/hr savings achieved and 1 is little or no savings achieved.)	_____	_____	_____	____
Operator Knowledge (Where 10 is a major effect and 1 is little or no effect.)	_____	_____	_____	_____
Productivity (Where 10 is a 50% improvement and 1 is little or no improvement.)	_____	_____	_____	_____
Engineering Skills (Where 10 is a major effect and 1 is little or no effect.)	_____	_____	_____	_____
Reduced Processing Time (Where 10 is a 50% improvement and 1 is little or no improvement.)	_____	_____	_____	_____
Teamwork and Work Structure (Where 10 is a major effect and 1 is little or no effect.)	_____	_____	_____	_____
Automation Potential (Where 10 could result in significant gains and 1 is little or no gains are likely.)	_____	_____	_____	_____
Managerial Skills (Where 10 is a major effect and 1 is little or no effect.)	_____	_____	_____	_____
Other(s)	_____	_____	_____	_____

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