Marketing Strategy Optimization: Using Linear Programming to Establish an Optimal Marketing Mixture

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INTRODUCTION AND BACKGROUND

Marketing strategy is vital to firm success since optimizing your marketing resources can assist in revenue generation and improve market share (Craig and Douglas 2000; Ohmae 1989; Yip 1995; Zou and Cavusgil 1996). As pointed out by Zou and Cavusgil (2002), while there are different global marketing strategy perspectives, they can be pursued simultaneously since they are not mutually exclusive. In fact, marketing efforts can vary, ranging from a concentration strategy directed at a single market segment to a multi-segment strategy focusing on several segments (Berkinshaw, Morrison, and Hulland 1995; Ohmae 1989, Porter 1986).

With the increasingly global marketplace, more companies are finding that optimizing their marketing efforts is becoming increasingly complex (Day 1994). This may be an even greater challenge when dealing with an extremely concentrated marketplace where a couple of the key competitors reside in a particular country like Japan (Johansson 1997). Couple these issues with the lack of agreement on what constitutes global marketing strategy, and strategy formulation becomes one of the largest challenges faced by many multi-national or global companies (Zou and Cavusgil 2002). In response to this increasingly complex analytical environment, managers are looking to more technical methods to assist in decision-making.

As a result, the focus of this research is on applying operations management techniques such as linear programming to assist marketing managers in determining the optimal marketing mix for a company engaged in exporting to several countries. Linear programming has proved to be a successful method of analysis for optimization problems of all types (Ignizio and Cavalier 1994). It is a tool valuable for modeling many and diverse types of problems in planning, routing, scheduling, assignment, and design. In fact, linear programming techniques have had broad appeal and have successfully been used in many industries including transportation, energy, telecommunications, and all types of manufacturing. For example, BASF utilized linear programming techniques to help them restructure their North American distribution system (Sery, Presti, and Shobrys 2001). Similarly IBM has used an analytical framework based on linear programming to better match their assets with demand levels throughout their supply chain (Lyon, Milne, Orzell, and Rice 2001). In both cases, the techniques lead to the revision of key strategies and resulted in significant performance improvement.

Current Study

The researchers selected a market characterized by a limited number of participants due to data availability and ease of the analysis for illustrative purposes. The market chosen was the manufacture of brazed aluminum heat exchangers (BAHX). The primary function of an aluminum heat exchanger is to effectively exchange heat between fluids. For example an automotive radiator is a small heat exchanger. While heat exchangers are common pieces of equipment, brazed aluminum heat exchangers are very unique for a variety of reasons

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including the compact size of the exchanger and the resistance to failure at certain temperatures.

Chart Heat Exchangers (CHX) is one of a very few companies that manufactures and distributes brazed aluminum heat exchangers globally. The key market participants included in this study and their home countries (Chart included) are: *Chart Heat Exchangers* – USA & UK, *Linde AG* – Germany, *Nordon Cryogenic* – France, *Kobe Steel* – Japan, and *Sumitomo Precision Products* – Japan (See Table 1). Given the relatively high level of competitive concentration in the market plus the unique company structure of each competitor, this market segment is ideal for application of a linear programming model to optimize one firm's marketing strategy.

DATA COLLECTION

During the early 1990's, the five primary brazed aluminum heat exchanger companies formed a manufacturers' association called ALPEMA (ALuminum Plate-fin heat Exchanger Manufacturers' Association). The primary functions of the association are two-fold: 1) to compile a book of standards for customers to utilize as specifications for new projects, and 2) to submit and compile market data in an effort for each competitor to understand its market position as well as the market trends. The market data is submitted to an independent party where it is compiled and reported in an agreed upon format in order to maintain confidentiality between the competitors. Therefore, the market data received by each supplier is for the total market only and not a breakdown of each competitor. Each supplier is able to ascertain its' own market share but not the market share of the other suppliers.

TABLE 1

Company Name	Location	Background
Chart Heat Exchangers	United States	Chart has a competitive presence globally, and is concentrated in North America, Europe, and parts of Asia. Recent acquisitions have led to an improved competitive position but also required some adjustment to their marketing strategy and marketing mix formulation.
Linde AG	Germany	Linde AG is a competitive force in Europe and the Middle East. Rarely does Linde AG attempt to compete in North America. For practical purposes, Linde AG is an operating unit of a large, vertically integrated company.
Nordon Cryogenic	France	Nordon's competitive presence is seen globally, however; its strongest presence is in Europe, particularly France. Nordon's French presence is obvious from a geographic standpoint. Additionally Nordon is highly vertically integrated since they are actually an old European division of the Trane Company.
Kobe Steel	Japan	Kobe Steel's competitive presence is often seen in Japan, Southeast Asia, and South America. Rarely is Kobe's presence seen in North America. Kobe is very vertically integrated since, for all practical purposes, it is an operating unit of a larger company.
Sumitomo Precision Products	Japan	Sumitomo's presence is strongest in the Pacific Rim (especially Japan), Europe, and North America. Sumitomo has a significant presence in the United States and is recognized as one of the technological leaders in the industry.

Chart Heat Exchangers recently purchased an outside entity in an attempt to consolidate competencies and improve their global competitive position. However, with any acquisition comes a need to alter the focus of the entity's worldwide marketing efforts. In an attempt to assist management in their quest to find the optimal marketing mixture, the current research strives to provide a practical linear programming model to assist practitioners with the optimization of marketing efforts.

Chart's recent company acquisition led to a European presence unparalleled in company history. Additionally, aside from Europe and North America, the remaining continents needed to be re-arranged and allocated among two operating divisions in order to avoid conflict and to maximize the worldwide marketing effort. As a result, the remainder of this paper will focus on how to analyze data, set an appropriate market strategy, and maximize global sales representation for Chart Heat Exchangers. Specifically the linear programming model will focus on marketing and sales efforts of the US sales office when examining how to handle the Japanese market.

Market data submitted from ALPEMA is complete through 2000, thus the scope of the analysis for this research will consider market data from 1993 to 2000. For most of the general discussion, the market size and share will be represented in dollars. However, due to the close correlation between sales dollars and volume, the volume of production is also considered in the analysis.

Considering that there are a total of five worldwide competitors, CHX's goal of capturing 40-45% of total market share is considered quite aggressive. Their marketing mix and strategy must be optimized if this goal is to be accomplished. While CHX will need to analyze their marketing strategy on a global scale, the scope of this research is to address CHX's sales representation and marketing strategy in Japan. In order to

gage the impact of the Japanese market to the market share and profitability of CHX, it is first important to understand the size and dynamics of the global and Japanese markets.

Japanese Marketplace

Current figures indicate the Japanese market represents only 1.7% of the total world market for BAHX, or, on average, about $2,500,000 per year in annual revenue. Knowing this, CHX's strategy and resource allocation both need to be planned accordingly. Additionally, due to the strong presence of Kobe Steel in Japan, there is a sector of the Japanese market that CHX will never be able to achieve competitive equality. Nevertheless, for multiple reasons, CHX management believes it is imperative to have a competitive presence in Japan. However, when competing in an industry characterized by a few key players, two based in Japan, exporting to Japan can create several unique challenges (Cavusgil and Zou 1987; Cavusgil, Zou, and Naidu 1993).

However, while at first glance the Japanese market may seem unattractive with only a mere 1.7% of the total market being represented by Japanese customers, it is believed by CHX's marketing professionals that the 1.7% dramatically understates current market share. This plus the tremendous growth potential in Japan has led CHX's management team to the belief that it is important to participate in the Japanese market. As it currently stands, Table 2 represents the market breakdown by Japanese customer as known by CHX. Table 3 illustrates a breakdown of CHX's customers and volume per customer in Japan. These tables help identify the largest Japanese customers and help direct CHX where to concentrate Japanese marketing efforts.

As evident from Tables 2 and 3, CHX's penetration is approximately 17% of the known competitive Japanese market share. This is well below CHX's average market share in other markets for the years 1993-2000 of approximately 29.3%. The total Japanese sales represent about 1% of the total CHX sales for the same time frame. Clearly, CHX's primary customers are JGC and Toyo (See Table 3). Total profit dollars from the years 1993 to 2000 is $678,626 at a Gross Before Commission (GBC) percent of 19.2%.

The figures presented above, as they relate to CHX's involvement in the Japanese market and the Japanese market as it relates to the world market as a whole, indicate that the Japanese market is relatively small with respect to CHX's total business. Nevertheless, as previously stated, CHX marketing professionals believe the Japanese market represents a much larger percent of the total world market. Unfortunately, due primarily to the limited reconnaissance of the Japanese market, current sales volume and future market potential are difficult to ascertain. However, given the strong possibility of an understated Japanese market plus low penetration levels by CHX, tremendous opportunities exist for CHX in Japan.

The average known sales per year of the Japanese market is $2,548,225. The average total world sales for all BAHX's annually is $145,812,500. The unknown CHX market data is approximately 40%; thus an average of $58,325,000 of the annual world market is not bid on by CHX. Table 4 illustrates various estimates of the actual Japanese market for BAHX's. The additional market column in Table 4 represents 0%, 20%, 40%, 60%, 80%,

TABLE 2

Year Customer	1993	1994	1995	1996	1997	1998	1999	2000	Total
Chiyoda	$0	$370,000	$1,600,000	$0	$0	$0	$0	$0	$1,970,000
Hitachi	$0	$326,000	$0	$0	$0	$0	$0	$0	$326,000
JGC	$1,519,300	$1,800,000	$0	$0	$2,450,000	$2,500,000	$0	$42,000	$8,311,300
Kobe	$0	$0	$0	$0	$0	$0	$0	$0	$0
MHI	$0	$501,800	$0	$0	$0	$0	$0	$0	$501,800
Nippon Sanso	$124,000	$0	$870,000	$0	$0	$0	$322,700	$0	$1,316,700
Toyo	$930,000	$275,000	$0	$3,155,000	$3,000,000	$0	$0	$600,000	$7,960,000
	$2,573,300	$3,272,800	$2,470,000	$3,155,000	$5,450,000	$2,500,000	$322,700	$642,000	$20,385,800

TABLE 3

Customer	Won Jobs	Market	Commission	Profit	*GBC
Chiyoda	$0	$1,970,000	$0	$0	0.0%
Hitachi	$0	$326,000	$0	$0	0.0%
JGC	$1,519,300	$8,311,300	$57,629	$300,540	19.8%
Kobe	$0	$0	$0	$0	0.0%
MHI	$501,800	$501,800	$12,043	$70,946	14.1%
Nippon Sanso	$446,700	$1,316,700	$0	$25,468	20.5%
Toyo	$1,058,000	$7,960,000	$59,127	$281,672	26.6%
Total	$3,525,800	$20,385,800	$128,799	$678,626	19.2%

* Gross Before Commission

and 100% of the unseen market (of the 40% unknown to CHX). The additional market is added to the current market figures to get the total market. Subsequently an average world market percentage is calculated. As a minimum CHX knows that the Japanese market comprises 1.7% of the average world market, however, as shown in Table 4, the Japanese market could theoretically be as high as 41.7%. With the above analysis of market potential coupled with the intuition CHX has about the Japanese market and other lesser known world markets, CHX believes that the Japanese market is more likely in the 10% - 20% range of the world market.

TABLE 4

Case	Japan Market	Additional Market	Total Market	% of World Market
0% additional Market	$2,548,225	$0	$2,548,225	1.7%
20% additional Market	$2,548,225	$11,665,000	$14,213,225	9.7%
40% additional Market	$2,548,225	$23,330,000	$25,878,225	17.7%
60% additional Market	$2,548,225	$34,995,000	$37,543,225	25.7%
80% additional Market	$2,548,225	$46,660,000	$49,208,225	33.7%
100% additional Market	$2,548,225	$58,325,000	$60,873,225	41.7%

With the above estimates of what the Japanese market actually could be, an analysis can be performed to assess the true viability of the Japanese market. Additionally, with the upside potential of the untapped Japanese market that is currently unrealized and unknown to CHX, it is essential that CHX study its marketing efforts and sales representation in Japan. The results of Table 4 will be utilized further in the analysis in order to help guide CHX to a marketing and sales force decision in Japan.

RESEARCH METHODOLOGY

In order to assist CHX with the marketing decision and sales representation structure, decision analysis is performed using basic tools from operations management. First, the results of a linear program analysis are presented. The linear program assists with identifying the current profitability of all of CHX's markets as well as the Japanese market. With the results of the linear program, CHX will be able to assess the profitability of using its assets in each market and, specifically, the level of resources to apply to the Japanese market. Next, an analysis of different options for CHX are presented and analyzed. The results of the analysis will assist CHX in determining the multitude of sales representation options in the Japanese market and ultimately, which option could lead to the most profitable strategy for CHX.

Optimal Marketing Mix Determination- A Linear Programming Framework

In order to help CHX identify the most profitable marketing mix with respect to its world market sector, a linear programming problem was formulated and solved. Essentially this linear program could be used by managers to attempt to find the most optimum level to maximize or minimize the given business function being analyzed. The first step in developing a linear programming problem is to identify the objective function (Ignizio and Cavalier 1994). The objective function is a linear mathematical relationship that describes the objective of the firm in terms of the decision variables being analyzed. In the case of CHX, the objective function is the profit maximization of the firm with respect to the global market sectors and the profitability of each sector. The next step in linear programming is to identify the decision variables. The decision variables are the mathematical components of the objective function that represent the activity of the firm. In the scope of this analysis the decision variables identify the level of business volume for each of CHX's global market sectors. Finally, the linear program analysis must be constrained. The modeled constraints are linear relationships of the decision variables. They represent the restrictions placed on the firm by the operating environment. In the current research, the operating environment constraints are the operating capacity at CHX, the market size, and the market share goals identified by CHX.

Linear Program Problem Formulation

The primary purpose of the linear programming analysis is to breakdown CHX's market sectors geographically, and determine which of these sectors produces the greatest profit. Therefore the objective function of the linear program is constructed to consider how much business volume CHX should produce for each of its market sectors while considering the profitability of each sector. In order to construct the profitability factors, decision variables, and constraints, the analysis for this particular problem will consider the eight-year averages for the variables and constraints for the years 1993 through 2000. Since past data analysis indicates CHX's business activities move in dramatic cycles, the researchers believe it is more appropriate to consider the average for these years rather than one-year specifically. Although using averages for this time frame has its weaknesses (such as consideration for inflationary factors in earlier years and the fact that historical averages don't always predict the

future), it is considered appropriate to use as a guidance tool for CHX.

Therefore the first step in constructing the objective function is to determine the profit per unit of product volume for each market sector. The information in Table 5 below summarizes the critical financial and product volume data in order to arrive at profit dollars per unit of product volume. The column on the far right of the table is the information to be used in the objective function as the profit dollars per unit of product volume. It is important to note that the Mexico, Pacific Rim (less Japan), and Other market sectors use the average profit dollar per unit of product volume ($/ft^3) (computed from the actual $/ft^3 values in the column second from the right). The reason for using the average for these market sectors is due to the fact the business generated in these sectors over the eight year period used to compute the average was so small that the actual $/ft^3 is abnormally high. Using an abnormal value in the objective function will yield skewed results of the linear program.

expected average profit level for CHX and the volume of product to be sold for each geographic market sector. This will inevitably lead to determining the optimal business level for CHX and the Japanese market and will help enable CHX to make a decision regarding the resources to dedicate to sales and marketing efforts in Japan.

Now that the objective function and decision variables are determined, the program model must be constrained. The operating environment to be constrained includes the CHX operating capacity, the market size, and the CHX market share goals. In considering the linear programming problem at hand, 21 constraints have been developed. Table 6 below lists the constraints and describes its general purpose. Please refer to Table 5, if the variable designation for each market sector needs to be reviewed.

Constraints 1 and 2 are set after determining the minimum and maximum factory volumes of the CHX operation. Constraints 4 through 11 set the minimum market size requirement for each market. Constraint

TABLE 5

Market	Variable	Average Sales	In Millions Average Cost	Average Profit	Average Volume (ft^3)	% of total volume	avg. $/ft^3	* used $/ft^3
USA	X1	$32,277	$19,458	$12,818	39937	84.5%	$321	$321
Canada	X2	$2,820	$1,760	$1,060	2295	4.9%	$462	$462
Mexico	X3	$298	$167	$131	148	0.3%	$889	$324
Europe	X4	$3,560	$2,896	$663	2129	4.5%	$312	$312
Japan	X5	$441	$356	$85	948	2.0%	$89	$89
Pac Rim	X6	$478	$268	$209	344	0.7%	$610	$324
South America	X7	$461	$310	$151	1394	2.9%	$108	$108
Other	X8	$423	$252	$170	57	0.1%	$2,970	$324
		$40,756	$25,467	$15,288	47252	100.0%	$324	$324

*Minimum average $/ft^3 is $324. In some market sectors the volume sold was so small that the profit/volume was skewed and would reveal unrealistic favoritism to these markets. Therefore the overall average profit/volume was used here.

The variables for each market sector are applied to the market sector identified in Table 5. Therefore the objective function to maximize profit dollars per unit of product volume can be written as follows:

$$Z = 321X1 + 462X2 + 324X3 + 312X4 + 89X5 + 324X6 + 108X7 + 324X8$$

The variables X1 through X8 are defined as the actual volume of product output by CHX for each market sector. Note that the product volume is measured in cubic feet. Cubic feet is the method that the ALPEMA membership report their market data when reporting on volume produced. This is also the method that is standard industry practice and CHX management uses to target manufacturing goals and set business forecasts. Considering the above objective function, the results of the linear program will yield the

3 requires that CHX not loose any market volume at all in North America (Canada, US, and Mexico). Data shows that North America is CHX's main source of current business and management feels this can not be compromised. Constraints 5 through 11 also consider that the market share in each sector must grow a minimum of 5%, or to a level of 400 $/ft^3 if the current market is less than 400 ft^3. This growth level was chosen as a reasonable growth rate in each of these sectors based on discussions with industry experts. Constraint 12 is simply the average market size data in product volume over the period 1994 to 2000 (1993 was not available, as ALPEMA did not start reporting this data until 1994); this is considered the average total world market size. Constraint 13 is the goal that has been vocalized to the researchers by CHX management. Constraints 14 through 21 are the maximum market sizes estimated for each market sector. Since

the ALPEMA data does not break down the global market sectors into this much detail, these market sizes are estimated. Table 7 provides data related to how these estimates were attained.

values must now be adjusted for CHX's awareness factor of each market sector.

As in the case of market share, CHX management knows that their overall awareness is 60%, however

TABLE 6

Constraint #	Formula	Description
1	X1+X2+X3+X4+X5+X6+X7+X8 >= 30,000	30,000 is the minimum factory volume to make CHX viable
2	X1+X2+X3+X4+X5+X6+X7+X8 <= 100,000	100,000 is CHX's maximum plant output
3	X1+X2+X3 >= 42,380	This requires that CHX will not lose market share in N. America
4	X1 >= 41,934	Minimum market share goal in US
5	X2 >= 400	Minimum market share goal in Canada
6	X3 >= 400	Minimum market share goal in Mexico
7	X4 >= 2236	Minimum market share goal in Europe
8	X5 >= 996	Minimum market share goal in Japan
9	X6 >= 400	Minimum market share goal in Pacific Rim
10	X7 >= 1464	Minimum market share goal in South America
11	X8 >= 400	Minimum market share goal in Other
12	X1+X2+X3+X4+X5+X6+X7+X8 <= 216,146	216,146 is average size of entire market - this cannot be exceeded
13	X1+X2+X3+X4+X5+X6+X7+X8 <= 86,458	86,458 is 40% of average total - this is CHX's market share goal
14	X1 <= 74882	This is the maximum average market size of the US
15	X2 <= 8607	This is the maximum average market size of Canada
16	X3 <= 11065	This is the maximum average market size of Mexico
17	X4 <= 56126	This is the maximum average market size of Europe
18	X5 <= 31608	This is the maximum average market size of Japan
19	X6 <= 11453	This is the maximum average market size of the Pacific Rim
20	X7 <= 18584	This is the maximum average market size of South America
21	X8 <= 3822	This is the maximum average market size of Other

TABLE 7

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
Estimated Market Sector	Chart Sector Avg. Volume	Sector Market Volume	Estimated Market Share	Overall Awareness	Total Market Overall Awareness	Adjusted Awareness	Chart Known Market	Total Market
USA	49921	39937	80.00%	60.00%	29953	90.00%	44929	74882
Canada	5738	2295	40.00%	60.00%	3443	90.00%	5164	8607
Mexico	7377	148	2.00%	60.00%	4426	90.00%	6639	11065
Europe	54910	2129	3.88%	60.00%	32946	61.33%	33675	56126
Japan	47411	948	2.00%	60.00%	28447	40.00%	18965	31608
Pac Rim	17179	344	2.00%	60.00%	10308	40.00%	6872	11453
South America	27877	1394	5.00%	60.00%	16726	40.00%	11151	18584
Other	5733	57	1.00%	60.00%	3440	40.00%	2293	3822
	216146	47252	21.86%		129688		129688	216147

The column containing CHX's market volume is known, Column 2. Also CHX's overall market awareness is known to be 60%. Additionally, CHX knows that its total market share over the eight-year time frame of 1993 to 2000 is 21.86% (it is much larger over the past three years due to a recent acquisition). Therefore market share estimates (Column 3) have been made proportionally for each market sector in order to maintain the overall known market share value of 21.86%. The estimated market share values have been allocated unequally to the market sector where CHX management believes they are winning or losing most of their business. From the estimated market share values CHX can then determine the estimated sector average volume as seen in Column 2 of Table 7. These these are also not uniform for each market sector. First the awareness factor of 60% is applied to the values of Column 2 to determine the values of Column 6. Column 7 contains the estimated actual adjusted awareness for each market sector in order to maintain the overall awareness of 60%. The values in Column 8 represent the actual product volume of market for each sector that CHX actually bids on. Finally, the values in Column 8 are readjusted using the overall awareness of Column 5 to obtain the total market values in Column 9. Certainly the estimates of market share and adjusted awareness for each sector can, and should, be put under scrutiny if CHX management utilizes this model to make decisions. However, for the scope of this research these are considered reasonable estimates and should be

within an order of magnitude of the actual values (if, in fact the actual values can even be determined).

RESULTS

The details related to the objective function and the constraints were entered into the linear programming model. The problem solution revealed the following results.

TABLE 8

Variable	X1	X2	X3	X4	X5	X6	X7	X8
Sector	USA	Canada	Mexico	Europe	Japan	Pac Rim	S. America	Other
Profit $/ft^3	321	462	324	312	89	324	108	324
Optimal Volume (ft^3)	**60357**	**8607**	**11065**	**2236**	**996**	**11453**	**1464**	**3822**

Resulting Profit $ 32,829,580

The profit is the result of the profit maximization of the objective function. This is the highest profit possible and is obtained when CHX produces the optimal volumes for each market sector. In reviewing the optimal volumes for each sector, with the exception of the USA market, it is found that the optimal volume is either limited by the minimum required growth in market share or the maximum size of the market. For instance the Canadian optimal market volume is 8607 ft^3 and the Japanese market is 996 ft^3. In this case, the linear program results indicate that CHX should allocate its resources in Canada in order to win 100% of its market size.

Conversely, the Japanese market optimal results indicate that only 996 ft^3 in product volume should be sought in this sector. In this case, the linear program identified the market maximum for Canada and the market minimum for Japan; this is due to the respective coefficients in the objective function of \$462/ ft^3 and \$89/ ft^3. Recall that the average profit per volume is found to be \$324/ ft^3; therefore for sectors with profit per volumes greater than the average, the linear program will seek to reach the market maximum. Likewise, for profit per volumes lower than the average, the linear program will seek to only attain the market minimum. The exception to this rule is the US market. In the case of the US market, the linear program seeks to fill all market sizes where the profit per volume is greater than the average and then it fills the remaining volume of CHX, limited only by the required market volume needed to achieve an overall share of 40%.

Clearly the linear program is dependent on the estimated market size of each sector, the required growth or minimum market size in each sector, and the profit per volume able to be achieved for each sector. Further study into the use of these values would be valuable to the linear program results. The intent of this paper is to provide, by means of the market data analyzed, some reasonable values for these variables and constraints in an effort to estimate the relative magnitude of the market size to be sought in each sector. The results can help to assist CHX management with making a decision regarding their Japanese sales and marketing efforts. If necessary, CHX management can conduct a more detailed analysis to challenge the estimates and assumption made herein.

The "Lower Bound" and "Upper Bound" of the variables indicate the level that, if the variable coefficient were changed (profit/volume), what level the variable coefficient would need to be changed to in order to affect the current solution. Therefore, since the "Upper Bound" for the Japanese market variable is 321, if the price per volume coefficient of the Japanese market were increase to \$322/ ft^3 the solution to the problem would change. Finally, one of the more notable items to review in the analysis is the "Dual Value" for the constraints. The "Dual Value" provides valuable information related to the constraint in that it indicates that if the constraint were changed by a small amount, the "Dual Value" would adjust the total maximized profit by the size of the "Dual Value". For instance, if the size of the Canadian market increased by 1 ft^3 then the total value for Z or the maximized profit would increase by \$141.

ANALYSIS OF LINEAR PROGRAM RESULTS

The results of the linear program indicate that the appropriate level of business volume is 996 ft^3. The 996 ft^3 value is achieved merely due to the fact that the linear program constraint for minimum market size in Japan is 996 ft^3. If CHX management decides that there is no minimum market presence in Japan, the linear program would indicate that the 996 ft^3 for the Japanese market should be sought in the US market. Since the US market is more profitable on a per volume basis than Japan, the linear program would indicate that 0 ft^3 is optimal for Japan.

Although not as profitable as other markets, the Japanese market still does produce profitable results. In competing in the Japanese market, CHX is able to discover valuable competitive information related to their Japanese competitors, Sumitomo and Kobe. Competitive reconnaissance reveals basic information such as pricing levels and lead time capabilities, but it also potentially reveals details related to other issues of the competition such as quality problems, changes in man-

agement, and sales and marketing strategy. With an estimate about the appropriate level of business to seek in the Japanese market, 996 ft^3, it can now be determined what would be the best option related to sales representation in Japan to support the level of business sought. An analysis of CHX's various options designed to achieve the optimal marketing alternative is discussed in the next section.

ANALYSIS OF CHX'S OPTIONS

A decision tree is used to help determine the best decision from a set of alternatives. The decision tree is a diagram that enables the user to see the decision making process and the alternatives in a clear, logical layout. CHX basically has five potential strategies to pursue regarding their Japanese operations. First, they can back out of Japan completely. Second, they can maintain their current Japanese strategy. Third, they can elect to modify their Japanese sales force commission payment system. Fourth, they can contract with a third party sales agent with already existing and superior relationships in the Japanese market. Fifth, they can hire a full time sales engineer in Japan in hopes to build a better relationship with Japanese customers. These five alternatives make up the options included in the decision tree analysis.

Decision Tree Results

Per the decision tree analysis results, the alternative possessing the maximum expected value of all the alternatives is to hire a local Japanese sales engineer. If CHX were basing their decision solely on the decision tree analysis, the Japanese sales engineer alternative is the marketing strategy that should be utilized by Chart Heat Exchangers. However, there are many subjective estimates that are utilized in this type of analysis. For instance, the probabilities of each of the profit scenarios are merely an educated estimation. Additionally the costs of compensation plans, commissions, and several other variables are merely educated hypotheses. To further test the impact of these estimates some decision calculus involving human analysis should be conducted to determine their impact on the final decision.

MANAGERIAL IMPLICATIONS

The results of the linear program indicate that a sales level based on product volume should be sought at a level of 996 ft^3. The results of the decision tree analysis produced a decision where CHX management should consider hiring a full time sales engineer in Japan and compensate the individual with a salary. However, it is unclear if this is 1) in the best interest of CHX, and 2) really a feasible alternative.

It has been proven that the profitability of the Japanese market is extremely low. However, while resource-based analytical methods are highly helpful in strategy formulation, it is necessary to anticipate how your strategy changes may alter the practices of others in a highly concentrated industry (Collins 1991, Grant 1991). For example, by attempting to steal market share from the Japanese competitors, CHX management believes the competitive reaction may be that more competitive pressure could be placed upon the North American market and subsequently drive the profitability of that market sector down. Furthermore, the competitive reconnaissance that participating in the Japanese market provides, may be valuable enough to sustain the lower than average profit levels that the Japanese market experiences. Therefore a relatively low volume in the Japanese market may be the strategy to pursue. As indicated from the sensitivity analysis of the potential market size of Japan, the sheer size potential of this market is great. Based on future market potential, CHX management can utilize the framework provided here to revise its strategies as its market share and profitability goals change. However, for the immediate future, CHX may simply want to seek a product volume of 996 ft^3 as the minimum sales goal for Japan, but attempt to incrementally increase this level annually.

In order to sustain the volume goal of 996 ft^3, CHX management may want to consider hiring a local Japanese sales engineer. However this should be approached with caution after management is fully aware of all the details. For example, there is always the concern that hiring and training such a person requires significant resources and takes significant amounts of time. Furthermore, CHX has indicated they would want to obtain a person that does not use the position as a training opportunity and then obtain another job either with another industry or more importantly with a direct CHX competitor. There tends to be a high degree of confidentiality in CHX's business; therefore CHX may want to minimize its exposure with respect to disclosure of confidential information. Conversely, from a sales and marketing perspective, hiring an indigenous person to have sole responsibility of selling the CHX product while compensating and informing him/her accordingly, will yield the most positive results. Nevertheless, there are several potential issues that may arise while pursuing this type of strategy.

CHX may also want to explore how they can induce positive behavior with foreign sales representatives through incentives and relationship building. Additionally, CHX could contact other firms in similar business environments and find out what strategies other companies have used to achieve success in promoting and selling product in Japan. CHX may also wish to consider pursuing additional ideas on the use of other analytical tools to use in analysis of the marketing problem.

LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

As indicated in both the linear programming and the decision tree analysis, the estimated and assumed variables should be validated. Those variables that cannot be validated should be further tested. Additional testing of these variables may produce different results and decisions; thus CHX management will have a better understanding of the interaction of the variables and the profitability of the Japanese market.

As previously stated, the scope of this paper is to analyze, set market strategy, and sales representation for Chart Heat Exchangers' US sales office for the Japanese market. Several recommendations have been offered utilizing the market data and decision analysis as well as some ideas on future research.

The operations management tools used within this paper are merely aids in assisting CHX management in breaking down the market data presented above. While much data has been obtained and analyzed, there still remains some unknown data and assumptions input into the decision tools. Therefore the decision tools provide merely a framework of analysis for CHX management as opposed to absolute answers to the problem being analyzed. As with all business problems, a certain degree of speculation must be made in predicting future events. In the case of the analysis provided, the results will attempt to speculate future outcomes based on historical data. It was not the intent of this paper to perform every possible scenario to test these assumptions, but rather to provide a framework for CHX management to arrive at marketing strategy decisions based on a valid framework.

REFERENCES

Birkinshaw, Julian, Allen Morrison, and John Hulland (1995), "Structural and Competitive Determinants of a Global Integration Strategy," *Strategic Management Journal*, 16(8), pp. 637-655.

Cavusgil, S. Tamer and Shaoming Zou (1994), "Marketing Strategy-Performance Relationship: An Investigation of the Empirical Link in Export Market Ventures," *Journal of Marketing*, 58(1), pp. 1-21.

Cavusgil, S. Tamer, Shaoming Zou, and G.M. Naidu (1993), "Product and Promotion Adaptation in Export Ventures: An Empirical Investigation," *Journal of International Business Studies*, 24(3), pp 479-506.

Collins, David J. (1991), "A Resource-Based Analysis of Global Competition: The Case of the Bearings Industry," *Strategic Management Journal*, 12 (Summer), pp. 49-68.

Craig, C. Samuel and Susan P. Douglas (2000), "Configural Advantage in Global Markets," *Journal of International Marketing*, 8(1), pp. 6-25.

Day, George S. (1994), "The Capabilities of Market-Driven Organizations," *Journal of Marketing*, 58(4), pp. 37-52.

Grant, Robert W. (1991), "The Resource-Based Theory of Competitive Advantage: Implications for Strategy Implementation," *California Management Review*, 33(3), pp. 114-135.

Ignizio, James P. and Tom M. Cavalier (1994), *Linear Programming*, Prentice Hall, Englewood Cliffs, NJ.

Johansson Johny K. and George S. Yip (1994), "Exploiting Globalization Potential: U.S. and Japanese Strategies," *Strategic Management Journal*, 15(8), pp. 579-601.

Ohmaw, Kenichi (1985), "Managing in a Borderless World," *Harvard Business Review*, 67 (May/June), pp. 152-161.

Peter Lyon, R. John Milne, Robert Orzell, and Robert Rice (2001), "Matching Assets with Demand in Supply Chain Management at IBM Microelectronics," *Interfaces*, 31(1), pp. 108-124.

Porter, Michael E. (1986), "Changing Patterns of International Competition," *California Management Review*, 28 (Winter), pp. 9-40.

Porter, Michael E. (1996), "What is Strategy?," *Harvard Business Review*, 74(6), pp. 61-78.

Slava Sery, Vince Presti, and Donald E. Shobrys (2001), "Optimization Models for Restructuring BASF North America's Distribution System," *Interfaces*, 31(3.1), pp. 55-65.

Yip, George (1995), *Total Global Strategy: Managing for Worldwide Competitive Advantage*. Englewood Cliffs, NJ: Prentice Hall.

Zou, Shaoming and S. Tamer Cavusgil (1996), "Global Strategy: A Review and an Integrated Conceptual Framework," *European Journal of Marketing*, 30(1), pp. 52-69.

Zou, Shaoming and S. Tamer Cavusgil (2002), "The GMS: A Broad Conceptualization of Global Marketing Strategy and Its Effect on Firm Performance," *Journal of Marketing*, 66(October), pp. 40-56.