CLASSIFICATION OF PRODUCTS FOR ALIGNMENT WITH SUPPLY CHAIN STRATEGY

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Abstract
A common characteristic of successful companies is strategic alignment of the supply chain from the purchase of raw materials to the delivery of the finished product. Although frameworks have been proposed to facilitate this alignment there is no consensus on the key characteristics to be used in describing products and the related market demand. This paper presents current research and approaches to the development of key product characteristics for the purpose of creating alignment within a supply chain strategy.

The research approach is described in detail along with the presentation of preliminary results from application of the research approach to an aerospace supply chain. Areas for future research are presented.

Keywords: Supply Chain, Product Demand, Product Classification

Introduction to Fisher's Framework

In 1997 Marshall Fisher made the claim that despite years of applied effort and resources there was no real evidence of significant improvement in supply chain performance. In this landmark article, Fisher suggested that the problem was in the improper alignment of product characteristics and supply chain strategy (Fisher, 1997). In most companies multiple products are produced and sold that possess different characteristics. A preponderance of these same companies employ a single supply chain strategy that is rarely challenged. "No matter how good the supply chain characteristics are, if the product fundamentally does not fit with the dominant supply chain design, optimum service and cost cannot be achieved" (Payne and Peters, 2004).

Fisher (1997) suggests that products can be classified in one of two categories, either functional or innovative based on the characteristics the product possesses and its market demand. Functional products satisfy basic needs and do not typically change over time. Demand for functional products is stable and predictable, improving the ability to forecast production needs. Functional products typically have a long life cycle and low profit margins. Access to market entry is easy, increasing the number of competitors.

Innovative products are often trendy, fashionable, or high tech and display highly variable demand. Since demand of new products is largely unknown, new products tend to fall into this category. Innovative products tend to have short life cycles and a high level of product variety. Profit margins for innovative products are significantly higher than for functional products thus, lost sales have a significantly more detrimental effect on the company bottom line performance (Fisher 1997).

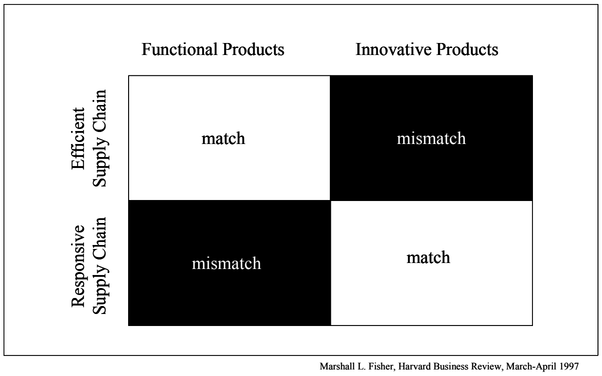
In reality, products have attributes that tend to make the product <u>more functional</u> or <u>more innovative</u>. It is possible for a product's characteristics to change as it matures or as customer requirements change (Harris and Componation, 2005).

Fisher is an acknowledged pioneer in the classification of supply chain strategies, claiming that there are basically two types of supply chain strategies, physically efficient and market responsive (Harris, 2007). In his framework Fisher proposes that for a company to be successful in the marketplace it must match functional products with an efficient supply chain strategy and innovative products should be aligned with a responsive supply chain strategy. Exhibit 1 provides a graphical depiction of this concept.

Efficient supply chains are focused on cost reduction and efficiency. Machine capacity utilization, productivity, and yields are all major considerations. The efficient supply chain attempts to create the most cost effective operation in the market by eliminating all non-value added activities. Economies of scale are pursued and resources are optimized wherever possible (Harris and Componation, 2005).

The purpose of the responsive supply chain is to meet customer demand regardless of the variation in demand. The key here is agility or flexibility within the supply chain. Supply disruptions are avoided by the use of strategically placed inventory. Agile supply chains possess the capability to respond successfully to customer, market and supply uncertainty (Lee 2002).

Exhibit 1. Fisher's Framework (Fisher 1997).



The concept of aligning functional products with physically efficient supply chains or innovative products with market responsive supply chains is uncomplicated, but many companies have not accepted that they must change and adapt (Fisher, 1997). Successful companies understand that their supply chain strategy must be designed to meet the needs of the customer and, as such, a product with stable demand and reliable supply cannot be managed the same as a product with unpredictable demand and erratic supply (Harris and Componation, 2005). The alignment of product characteristics with the appropriate supply chain strategy benefits the organization well beyond the positive effects on cost, productivity, efficiency and competitiveness. It allows the company to be more competitive in the marketplace where it has been suggested that the only true competition is between supply networks (Christopher and Towill, 2002).

The Need for Product Classification Tools

A review of the supply chain literature shows that there is no consensus on the critical components to product classification. If alignment is to be achieved there needs to be a universally accepted methodology for the classification of products according to characteristics (Harris et al., 2006).

Research by Harris (2007) revealed that "managers and practitioners need tools to aid in the alignment of product types and supply chain strategies to optimize the performance of the network." This need is also noted by others who state that if managers are to make reasonable decisions, a framework is needed that can be used to help them understand the nature of the market for their products and the supply chain design that will best satisfy that market. The result of non-alignment of products with an appropriate supply chain results in over serving and over charging customers of functional products and under serving and under charging customers for innovative products. Developing an appropriate supply chain for a product/customer combination should be based on achieving the right balance between the required levels of customer service and the total cost of supplying that level of service (Payne and Peters, 2004; Thirumalai and Sinha, 2004).

Research Approach

The approach taken in the research was to first examine the existing methods related to determing the product characteristic in support of supply chain alignment. Next a proposed method that is more comprehensive than the existing methods will be discussed. Finally the proposed method will be evaluated in an existing supply chain to determine if the proposed method is more comprehensive than the existing methods.

Existing Methods

There are three documented methods that address product characterization selection: DWV³ (Christopher and Towill, 2000), the three dimensional global classification system (Christopher and Towill, 2002) and the key determinants as determined by the OEM (Payne and Peters, 2004). Each of these methods either recommends a defined set of product characteristics or relies on the prime contactor to determine which product characteristics are most appropriate for their supply chain. A brief explanation of each of the three methods is listed below.

The DWV³ method utilizes five (5) product characteristics: duration of life cycle, time window for delivery, volume, variety and varability. Christopher and Towill (2000) recommended that those five (5) characteristics would be adequate in defining the supply chains based on their experience in the garment industry and focused on the final assembler or original equipment manufacturer.

The three dimensional global classification system was also developed by Christopher and Towill (2002) and utilizes three (3) product characteristics: product, demand and lead-times They proposed that each characteristic be classified in one of two gradations:

- Product (standard or special)
- Demand (stable or volitale)
- Lead-time (short or long)

Payne and Peters (2004) utilized seven (7) product characteristics the original equipment manufacturer deemed important in the development of their Product Supply Characterization (PSC) model. In all cases the suppliers who provide parts to the supply chain were not consulted for input on the characteristics.

All three of these methods recommended numbers of product characteristics that are significantly lower than the fifteen developed by Harris et al. Aitken et al. (2003) state, "To keep a handle on any classification system, the variables need to be kept to a minimum and the levels for each variable need to be as few as possible. If not, the alternatives to be considered by the analyst expand very quickly. For example if DWV³ codification levels are selected to be binary for each variable there are already 32 supply chains theoretically needed to meet demand across the product range. No business could economically set up so many discrete pipelines. Nor, indeed, would it be wise to do so, since operations management overheads thereby escalate."

Proposed Method

In order to effectively determine which supply chain product characteristics are the most appropriate for supply chain alignment a method to down select from fifteen to a manageable number must be determined. The development of a questionnaire that asks the participants to rank their top product characteristics would be logical. However to develop such a questionnaire various boundaries must first be established.

In developing a questionnaire, the first question that needs to be answered would be the number of product characteristics that need to be ranked by the participants. In the previous section it has been determined that utilizing all fifteen characteristics is not a feasible option. The DWV³ (Christopher and Towill, 2000) and the three dimensional global classification systems (Christopher and Towill, 2002), utilize five and three product characteristics respectively. Fisher (1996) utilized seven product characteristics in describing this Supply Chain Alignment Matrix. Payne and Peter's (2004) also utilized seven product characteristics in the development of their Product Supply Characterization (PSC) model. Based on the previous research, seven product characteristics appear to be sufficient to support this analysis.

The next question that needs to be answered is how one structures a questionnaire that effectively determines the most important product characteristics. Simply asking the participants to select from the product characteristics developed by Harris et al. (2006) without proper definition of measurement could produce inconsistent results. How one participant interprets the product characteristic "demand" may be total different than how another participant interprets the same product characteristic. Thus the need to define the measurable attributes of each product characteristic. Exhibit 2 contains those attributes in addition to the remaining fourteen product characteristics. The questionnaire would need to be developed utilizing the key measurable attributes to define each product characteristics.

Exhibit 2. Product Characteristic Attributes

Product Characteristics	Measurable Attributes
Demand	Variability, predictability, volatility and volume
Cost	Supply chain, inventory and manufacturing
Quality	Defects and percent yield
Product	Physical characteristics
Financial	Profit margin per part
Lead-time	Response time to deliver the product
Inventory	Product held in kanban/JIT inventory
Flexibility	Ability to handle change in demand, design and delivery
Delivery	On-time/on-schedule
Uncertainty	Customer demand and market environment
Life Cycle	Phase and length of time in phase
Customer	Responsiveness in service
Production	Capability and capacity to produce in lean environment
Design	Manufacturability of the product
Standardization	Few customized features of the product

The final question is who participates in the process to determine which product characteristics are the more applicable. As stated earlier, previous research in this area had relied upon the researcher's experience or the Original Equipment Manufacturer's point of view to evaluate which product characteristics were the most applicable. However in the last decade outsourcing has become a key strategy in maintaining global competitiveness thus emphasizing the role of the suppliers. Therefore is seems only logical to include the various supply chain tiers in the analysis.

A questionnaire was then developed that utilized the measrurable attributes in Exhibit 2 to define the product characteristics. The participants would be asked to rank the their top seven (7) most important product charatertistic they deemed important in order to effectively support their customer. If the participants selected the product characteristics from the two existing methods (DWV³ (Christopher and Towill, 2000) and/or the three dimensional global classification systems (Christopher and Towill, 2002)), the existing methodologies may be sufficient, however if they selected characteritics that were not in either of those methods, the existing methodologies may not be adequate. Since the DWV³ method contained two (2) characteristics of demand (variability and volume), the demand product characteristics was expanded in the questionnaire to include those two options for demand.

The questions were then randomly sorted using the RANDBETWEEN function in Microsoft ® Office Excel 2003 to randomly assign the order of the product characteristics.

Questionaire Distribution

An existing Department of Defense avaiton platform supply chain was chosen to evaluate if the proposed method was more comprehensive than the existing methodolgies. Questionnaires were submitted to the prime contractor, first tier suppliers, second tier suppliers and material suppliers to determine their top seven (7) product charateristics they deemed important to effectively support their customer.

The prime contractor is responsible for the design, manufacturing, systems integration and support of the specific aviation system (i.e. airplane or helicopter). The first tier suppliers primarily provide parts and/or subassemblies to the prime contractors which are ready for assembly to the vehicle (i.e. machine shops). Second tier suppliers provide products to the first tier suppliers. Companies that provide products for this specific supply chain include bearing manufacturers and forging houses. The last level of the supply chain is the material suppliers. In this study the only companies classified as material suppliers where the mills that manufactured the raw material. It should be noted that the material distributors were classified as second tier suppliers.

The respondents were also asked selected their least three (3) important product characteristics. If the respondents selected any of the product charateristics as least important, this would assist in determining if the proposed method was more comprehensive than the existing methods. The details of submittals and responses by supply chain tier are shown in Exhibit 3.

Exhibit 3. Responses by Supply Chain Tier

Supply Chain Tier	Questionnaires Submitted	Questionnaires Completed	Response Rate
Prime Contractor	5	5	100%
First Tier Suppliers	29	23	79%
Second Tier Suppliers	21	14	67%
Material Suppliers	6	4	67%
Totals	61	46	75%

Sixty-one questionnaires were submitted to various levels of the supply chain with fourty-six respondents for a 75% response rate. In this research, five personnel representing various functions within the prime contractor were surveyed. One-hundred percent of these personnel participated in the study. In each of the remaining organizations only one person from each company participated in the study. Twenty-nine first tier suppliers were asked to participate in the research with twenty-three completing questionnaires. Fourteen of the twenty-one of the second tier supplier participated in the research. Six material suppliers were requested to participate in the research with four completing the questionnaires.

Prelimany Results

Exhibit 4 shows the results from the respondents to the questionnaire. The first column is the list of the product characteristics in order as determined by all respondents. Each of the supply chain tiers average reponse ranking for the product charateristics is listed in the next colums. The last two columns contains the product characteristics recommended by the two existing methods.

Exhibit 4. Questionnaire Results by Supply Chain Tier

Product Characteristics by Response (to customer)	Total Rank	OEM Rank	1st Tier Rank	2nd Tier Rank	Material Supplier Rank	DWV³	3D
Delivery	1	1	1	3	2	X	
Lead-time	2	2	2	2	1		X
Cost	3	6	3	6	5		
Design	4	11	4	1	15		
Product	5	16	5	4	3		
Flexibility	6	3	9	5	9.5		
Demand (Variability/Predictability)	7	8	8	8	4	X	
Demand (Volatility/Volume)	8	12	6	9	13	X	X
Quality	9	7	7	10	14		
Production	10	4	10	12	7		
Financial	11	10	11	7	12		
Customer	12	5	12	11	6		
Inventory	13	9	15	13	9.5		
Standardization	14	15	14	14	8	X	X
Life Cycle	15	13.5	13	16	11	X	
Uncertainty	16	13.5	16	15	16		

Based on these findings, only two (2) of the five (5) DWV³ (Christopher and Towill, 2000) and one (1) of the three (3) global classification systems (Christopher and Towill, 2002) product charateristics were selected in the top seven (7) characteristics from the respondents. Just as important, the same number of the DWV³ and global classification system product characteristics were selected in the three (3) least important characteristics.

In order to evaluate the key determinants as determined by the OEM method (Payne and Peters, 2004), further analysis is required. It must be determined if the product characteristics selected by the OEM correlates to those selected by the suppliers. The Spearman's Rho correlation method was selected to perform a statistical analysis between the ranked product characteristic responses between the OEM and their suppliers.

The measure of correlation for Spearman is designated by Rho (ρ) and is defined by Conover (1980) as:

$$\rho = 1 - \frac{6T}{n(n^2 - 1)} \quad (1)$$

where:
n = sample size
$T = \sum [R(Xi) – R(Yi)]^2$ for i = 1 to n (2)
R(Xi) = rank of the first data set
R(Yi) = rank of the second data set

A positive ρ indicates that positive correlation exists like wise a negative ρ indicates that a negative correlation exists. However, this analysis alone does not determine if sufficient evidence exists to make statistical inferential conclusions on the data. Spearman's Rho permits hypothesis testing to determine if Xi and Yi are mutually independent (H0) or that there is a tendency for the larger values of X to be paired with the larger values of Y or the smaller values of X to be paired with the larger values of Y for two data sets being analyzed (H1). The null hypothesis (H0) for this particular analysis is the ranks for the product characteristics selected by the two populations of the supply chain do not agree or are not correlated. The alternative hypothesis (H1) would be there is either positive or negative correlation between the rankings of the product characteristics selected by the two populations.

The decision rule for Spearman's Rho utilizes tables entitled, "Quantiles of the Spearman Test Statistic" (Conover, 1980) in the hypothesis test. The test statistic is determined by the number of observations being compared and the selected level of significance (α). For this analysis, the number of observations is 16 and the level of significance is assumed to be α = .05. Since this hypothesis is a two-tailed test, the significance level is α = .025 (α/2). From the tables, the quantiles (w(p)) for this analysis are w(p) = .5000 for the upper quantiles and w(p) = -.5000 for the lower quantiles. Based on this information, the decision criteria for this analysis is to reject H0 if ρ is greater than .5000 or if ρ is less than -.5000. Exhibit 5 contains the summary of the rankings for the prime contractor versus all suppliers along with the T calculation (i.e., the squared difference between the rankings.)

Exhibit 5. OEM versus Supplier Results

Product Characteristics by Response (to customer)	Total Rank	OEM Rank	All Suppliers	DWV^3	3D	T
Delivery	1	1	1	X		0
Lead-time	2	2	2		X	0
Cost	3	6	5			1
Design	4	11	3			64
Product	5	16	4			144
Flexibility	6	3	7			16
Demand (Variability/Predictability)	7	8	8	X		0
Demand (Volatility/Volume)	8	12	6	X	X	36
Quality	9	7	9			4
Production	10	4	11			49
Financial	11	10	10			0
Customer	12	5	12			49
Inventory	13	9	14			25
Standardization	14	15	13	X	X	4
Life Cycle	15	13.5	15	X		2.25
Uncertainty	16	13.5	16			6.25
T = OEM vs. All Suppliers					T =	400.5

Utilizing the T calculation, Spearman's Rho can be calculated as follows:

$$\rho = 1 - [6 ((400.5)) / (16(16^2 - 1))] = 0.4110 \quad (3)$$

A positive correlation exist between the two populations since ρ is positive, however since ρ does not exceed .5000 as defined by the decision rule, the analysis fails to reject H0 and conclude that the OEM and the suppliers do not agree on which product characteristics are most important in their organizations ability to effectively supply parts to their customers.

Conclusions and Next Steps

The proposed methodology appears to be more comprehensive that the three (3) existing methodologies. Not only did the respondents select the majority of the product characteristics from the proposed methodology, the respondents selected 40% of the DWV^3 (Christopher and Towill, 2000) and 33% of the three dimensional global classification system (Christopher and Towill, 2002) product characteristics as least important. In regards to the methodology utilized by Payne and Peters (2004), based on the Spearman Rho's analysis, the suppliers were not in agreement with the product charaterstics selected by the OEM. This finding indicates possible collaboration issues between the supply chain tiers. Further research in this area is warranted.

Future reseach that examines the product charateristics between supply chain levels and their correlations is planned. An analysis between supply chain tiers that compares the expecations the customer has from the supplier and what the supplier anticipates from the customer will also be examined. The supply chain under evaluation will also be analyzed to determine if it is aligned according to Fisher's framework and if the current supply chain type is effectively supporting customer requirements.

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