Product Characteristics: The Establishment of Key Attributes for Product Classification

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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 analyzes the current research literature to develop common product attributes and suggests key attributes to further research into product characteristics and supply chain alignment. Ultimately, a methodology for classifying products by key characteristics and mapping to the appropriate supply chain is the goal. **Keywords:** Supply Chain, Product Demand, Product Classification

1. Introduction

In his 1997 article in the Harvard Business Review, Marshall Fisher [1] stated that after years of effort very little real improvement had actually taken place in supply chain performance. Fisher suggested that perhaps the problem was that supply chain strategy was not aligned with the characteristics of product demand. Payne and Peters [2] asked a similar question. “Why do companies still struggle to get the maximum service and minimum cost from their supply chains?” Companies often sell many different products with different characteristics in different markets, yet they utilize a single supply chain design that is rarely challenged. This could be part of the problem. “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.” [2]

Fisher [1] suggested that products could be classified as either functional or innovative based upon certain characteristics of the product and its market demand. A functional product satisfies basic needs and typically does not change over time. Demand is stable and predictable, making the demand easier to forecast. The functional product exhibits a long life cycle and typically generates low profit margins due to the ease by which competitors can enter the market and the cost of obsolescence is low. The innovative product is at the opposite end on the spectrum. These products are often trendy, fashionable, or high tech and exhibit highly variable demand. New products tend to fall into this category since the initial demand is largely unknown. Innovative products also tend to have short life cycles and greater product variety. The profit margin for innovative products is higher than that of functional products and thus, lost sales have a much greater effect on company performance.

Fisher proposed the idea that products could be classified as either functional or innovative but did not purport that these were discrete or definitive types and that all products would fall neatly into one of the two classifications. He acknowledged that products were primarily functional or innovative, exhibiting characteristics that would lead to a classification based on the preponderance of those characteristics [1]. 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 [3].

Although there has been some analysis and discussion that a product classification system is needed, a review of the supply chain literature to-date indicates that there is currently no consensus on the critical components of such a product classification system. To achieve alignment there needs to be a universally accepted methodology for the classification of products according to characteristics. The alignment of supply chain and product characteristics benefits the organization beyond the positive effects on cost, productivity, efficiency and competitiveness. In fact, it has been suggested that companies no longer compete, but that competition is actually between supply networks [4].

For managers to have the information required to make reasonable decisions a framework is needed that can aid in understanding 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 [2, 5].

2. Existing models and frameworks

During the literature review conducted for this paper, two existing models or frameworks were of particular interest, the DWV^3 model [6] and the Product Supply Characterization (PSC) Model [2]. The DWV^3 model was developed to segregate products according to their supply chain requirements. The DWV^3 is an acronym that represents five key supply chain variables; Duration of life cycle, time Window for delivery, Volume, Variety and Variability. Each variable can be defined with various classification types (e.g. short or long lead times, low or high volume) depending on the product(s). The idea is to align products, based on the characteristics of the five variables, with the main objective to align a vast majority (95%) in a manageable number (4 to 6) of different type of supply chains. Examples of supply chain types are build-to-order, kanban, postponement and distribution centers. The DWV^3 model was developed by Christopher and Towill based on their industrial experiences and a pre-2000 literature search [6].

The Product Supply Chain (PSC) model developed by Payne and Peters [2] incorporates “true” supply chain cost into the model. The costs must be developed from the “bottom up” to provide a total picture. Payne and Peters add that, “Traditional costing approaches (such as absorption costing) do not reflect the true costs of sending a particular order through a particular supply chain. Hence, without proper visibility of true supply chain costs the necessary rebalancing and optimizing cannot be achieved.” Much like the DWV^3 model, the PSC model attempts to align a majority of the products to a manageable number of different supply chain types. The main difference is that it uses true supply chain cost as the key performance metric (differentiator) and relies upon specific company attributes to determine the key supply chain metrics to be used in the analysis. The object of our research is to include post-2000 research regarding product attributes not focused on one particular company or industry.

3. Analysis of Characteristics/Attributes

A review of the Supply Chain research literature identified 73 articles in refereed journals that directly referenced Fisher’s original Harvard Business Review article [1]. The 73 articles identified were used to determine the product characteristics considered for classification into product types. In this collection of articles there were 484 references deemed important to product classification with no significant consensus among the authors. The 484 references were analyzed and grouped into 46 broad characteristics based on similar intent. Table 1 presents a frequency analysis showing how many of the 484 references are included in each characteristic category. Initially a frequency of 10 or more was used to keep a broad approach to the analysis through the first cut of the data. This step resulted in a list of 14 characteristics that were retained for further analysis.

A second analysis was performed to cross validate the key categories obtained from the first analysis. Using Google Scholar, we were able to determine the number of occasions that each paper had been cited by other authors. Any paper with 5 or more citations was included in the second analysis. Twenty-Three papers were most frequently cited and seem to have established the authors as experts in the field. These papers were analyzed and 129 product characteristics were mentioned. Table 2 shows a frequency analysis of these 129 product characteristics. An initial cut off was made at 14 characteristics that coincided with any group with more than 3% of the total references. Further investigation indicated that the characteristic *Standardization* was in the 23-paper analysis but had not made final list in the total analysis. The characteristic *Production* had made the total analysis list of characteristics but not the characteristics list in the cross-validation study. In all, there were 13 common characteristics between both analyses. With this information available, the authors decided to continue our analysis of the characteristics using 15 total characteristics consisting of 13 characteristics included in both analyses and the *Standardization* and *Production* characteristics.

Table 1. Frequency Analysis - Product Characteristics Mentioned by Authors in Referenced Articles

Characteristic	#	%		Characteristic	#	%		Characteristic	#	%
Demand	53	10.95%		Product Devel.	8	1.65%		Response	2	0.41%
Cost	52	10.74%		Order	8	1.65%		Innovative	2	0.41%
Quality	36	7.44%		Customization	8	1.65%		Complexity	2	0.41%
Product	30	6.20%		Management	7	1.45%		Technology	1	0.21%
Financial	29	5.99%		Value	6	1.24%		Proprietary	1	0.21%
Lead Time	26	5.37%		Forecast	6	1.24%		Overproduction	1	0.21%
Inventory	24	4.96%		Cycle Time	6	1.24%		Marketing	1	0.21%
Flexibility	24	4.96%		Standardization	4	0.83%		Information	1	0.21%
Delivery	24	4.96%		Obsolescence	4	0.83%		Homogeneity	1	0.21%
Uncertainty	21	4.34%		Fill Rate	4	0.83%		Heterogeneity	1	0.21%
Life Cycle	14	2.89%		Competition	4	0.83%		Functional	1	0.21%
Customer	14	2.89%		Capacity	4	0.83%		Damage	1	0.21%
Production	13	2.69%		Supplier	3	0.62%		Collaboration	1	0.21%
Design	11	2.27%		Metrics	3	0.62%		Availability	1	0.21%
Service	8	1.65%		Efficiency	3	0.62%				
Reliability	8	1.65%		Stability	2	0.41%			484	

The complete analysis resulted in the inclusion of the following product characteristics in the initial stage in the evaluation: *Demand, Cost, Quality, Product, Financial, Lead Time, Inventory, Flexibility, Delivery, Uncertainty, Life Cycle, Customer, Production, Design*, and *Standardization*. The next step was to perform a more detailed analysis to more thoroughly investigate how each author defined each particular characteristic. This step was essentially a secondary validation of the allocation of characteristics to categories. In the initial review of the 73 articles, characteristics were identified and categorized. In the secondary validation, attributes of these characteristics were identified. In most instances, there was more than one attribute associated with a characteristic in an article. The result is a larger number of attributes than characteristics overall in the data. Table 3 presents the secondary validation of the characteristic entitled *Demand*. After finding and dissecting each of the 53 references that had been assigned to the *Demand* characteristic, the attributes in Table 3 emerged.

Table 2. Frequency Analysis - Product Characteristics Mentioned in 23 Most Cited Papers

Characteristic	#	%		Characteristic	#	%		Characteristic	#	%
Demand	14	10.85%		Standardization	4	3.10%		Capacity	2	1.55%
Quality	10	7.75%		Design	4	3.10%		Order	2	1.55%
Financial	10	7.75%		Customer	4	3.10%		Cycle time	2	1.55%
Cost	8	6.20%		Service	3	2.33%		Technology	1	0.78%
Lead Time	7	5.43%		Production	3	2.33%		Supplier	1	0.78%
Life Cycle	6	4.65%		Obsolescence	3	2.33%		Overproduction	1	0.78%
Inventory	6	4.65%		Management	3	2.33%		Homogeneity	1	0.78%
Uncertainty	5	3.88%		Forecast	3	2.33%		Availability	1	0.78%
Product	5	3.88%		Value	3	2.33%		Fill Rate	1	0.78%
Flexibility	5	3.88%		Product Devel.	2	1.55%		Management	1	0.78%
Delivery	5	3.88%		Customization	2	1.55%		Reliability	1	0.78%
									129	

In order to establish a manageable number of attributes for the product classification framework only those attributes with 10% or more references are included in the list of potential model variables. Based on this analysis, *variability* (26.8%), *predictability* (19.6%), *volatility* (14.3%) and *volume* (12.5%) are candidate attributes to be included in the evolving framework for product classification.

Table 3. Attributes of the Characteristic *Demand*

Volume	Variability	Uncertainty	Predictability / Forecast Accuracy	Volatility	Change in Variability / Dynamism	Heterogeneity	Freq of Orders	Number of Customers	Complexity	Expectations	Flexibility
12.5%	26.8%	3.6%	19.6%	14.3%	7.1%	1.8%	3.6%	1.8%	1.8%	3.6%	3.6%

The next stage in the evaluation was to establish whether the characteristic could be measured and modeled. To determine this, each of the attribute definitions presented in the literature was analyzed in order to formulate a "consensus" definition of the category. For the purposes of this research, the resulting definitions for the attributes of the characteristic *Demand* are:

- *Variability* is the Range of order quantities over a period of time. [6,7,8,9,10,11,12,13]
- *Predictability* is determined by the ability to forecast demand accurately. [14,15,16,17,18,19,20]
- *Volatility* is determined by the frequency or rapidity of changes in orders. [15,17,20]
- *Volume* is the quantity of products sold. [2,6,11,14,19]

The significant feature of each of these attributes of *Demand* is that they can be directly measured and could be modeled given knowledge of the market for each product to be classified. Therefore, to adequately describe the *Demand* characteristic in the product classification framework we could now include *variability*, *predictability*, *volatility* and *volume* in the list of potential product classification attributes. The procedure outlined in this paper is currently being utilized to evaluate the other 14 characteristics to determine a complete set of characteristics that could be used to develop a common product classification framework. This framework could then be used to develop models to evaluate the performance of particular supply chain strategies for different product types.

4. Conclusions and Further Research

The missing component that is critical to furthering the research and understanding of product and supply chain alignment is a common set of key characteristics that can be utilized in any industry to determine product classification. This paper has presented a methodology for assessing the current research literature to ascertain these key characteristics in the area of Supply Chain Alignment Theory. The ultimate goals are to develop a methodology for the classification of products by key characteristics, a mapping to the appropriate supply chain strategy, and the development of a model for evaluating supply chain performance when aligned with products of different classifications. Benefits of aligning the product characteristics with the appropriate supply chain are evident in reduction of costs and increased productivity and efficiencies in supply chain operations. The increased performance increases the overall competitiveness of the supply chain, the basis of competition in today's environment.

Based upon the preliminary research reported here, it is important to continue the effort into this area and complete the process to establish a common set of characteristic attributes to be used in the classification of products. Without a common set of core product characteristics empirical proof of the Supply Chain Alignment Theory will not progress beyond a plausible idea with islands of success but no clear demonstration of total supply network improvement. Further research is needed to complete the development of a product classification system with a common set of characteristics that can be used to evaluate a wide array of products in many industries. This common framework would allow the research of Supply Chain Alignment Theory to move forward at a more rapid pace. Additional research should be performed on supply chain characteristics to develop the other major components in Supply Chain

Alignment Theory. To develop objective conclusions from this research a survey of industry supply chain managers should be conducted. The authors are currently working on this survey with intensions of publishing the results in a future article. Performance metrics that result in behaviors that support Supply Chain Alignment Theory must be developed if any gain made by the actual alignment of products and supply chains is to be sustained. To empirically evaluate Supply Chain Alignment Theory, models must be developed to investigate the effect of alignment and misalignment. The authors are currently pursuing these areas of research and will be reporting on the results in future articles.

5. References

[1] Fisher, M. L., 1997, "What Is the Right Supply Chain for Your Product?" *Harvard Business Review*, (Mar-Apr): 105-116.

[2] Payne, T., and Peters, M. J., 2004, "What Is the Right Supply chain for Your Products?" *The International Journal of Logistics Management*, 15 (2), 77-92.

[3] Harris, G.A., and Componation, P.J., 2005, "Aligning Supply Chain Strategy with Product Demand Characteristics", Proc. of the Huntsville Simulation Conference 2005, Oct. 26-27, Huntsville, AL.

[4] Christopher, M., and Towill, D.R., 2002, "Developing Market Specific Supply Chain Strategies," *International Journal of Logistics Management*, 13 (1), 1-14.

[5] Thirumalai, S. and K.K. Sinha, "Customer Satisfaction with Order Fulfillment in Retail Supply Chains: Implications of Product Type in Electronic B2C Transactions," *Journal of Operations Management*, 23, 291-303.

[6] Aiken, J., Childerhouse, P., and Towill, D.R., 2003, "The Impact of Product Life Cycle on Supply Chain Strategy," *International Journal of Production Economics*, 85, 127-140.

[7] Kulp, S.C., Lee, H.L., and Olfek, E., 2004, "Manufacturer Benefits from Information Integration with Retail Customers," *Management Science*, 50 (4), 431-444.

[8] Chen, I.J., and Paulraj, A, 2004, "Understanding Supply Chain Management: Critical Research and a Theoretical Framework," *International Journal of Production Research*, 42 (1), 131-163.

[9] Disney, S.M., and Towill, D.R., 2003, "The Effect of Vendor Managed Inventory (VMI) Dynamics on the Bullwhip Effect in Supply Chains," *International Journal of Production Economics*, 85, 199-215.

[10] Holweg, M., 2003, "The Three-day Car Challenge: Investigating the Inhibitors of Responsive Order Fulfillment in New Vehicle Supply Systems," *International Journal of Logistics: Research and Applications*, 6 (3), 165-183.

[11] Wong, C.Y., Arlbjorn, J.S., Hvolby, H., and Johansen, J., 2005, "Assessing Responsiveness of a Volatile and Seasonal Supply Chain: A Case Study," *International Journal of Production Economics*, Article in Press – Corrected Proof, 1-13.

[12] Das, S.K., and Abdel-Malek, L., 2003, "Modeling the Flexibility of Order Quantities and Lead-Times in Supply Chains," *International Journal of Production Economics*, 85, 171-181.

[13] Yang, K., Ruben, R.A., and Webster, S., 2003, "Managing Vendor Inventory in a Dual Level Distribution System," *Journal of Business Logistics*, 24 (2), 91-108.

[14] Lee, H.L., 2002, "Aligning supply chain strategies with product uncertainties." *California Management Review*, 44 (3), 105-119.

[15] Christopher, M., and Towill, D.R., 2000, "An Integrated Model for the Design of Agile Supply Chains," Working Papers, www.martin-christopher.info/downloads

[16] Mason-Jones, R., Naylor, B. and Towill, D.R., 2000, "Lean, Agile or Leagile? Matching Your Supply Chain to the Marketplace," *International Journal of Production Research*, 38 (17), 4061-4070.

[17] Yang, B., Burns, N.D., and Backhouse, C.J., 2004, "Management of Uncertainty Through Postponement," *International Journal of Production Research*, 42 (6), 1049-1064.

[18] Wang, G., Huang, S.H., and Dismukes, J.P., 2003, "Product-Driven Supply Chain Selection Using Integrated Multi-Criteria Decision-Making Methodology," *International Journal of Production Economics*, 91, 1-15.

[19] Yang, B., and Burns, N., 2003, implications of Postponement for Supply Chains," *International Journal of Production Research*, 41 (9), 2075-2090.

[20] Lee, H.L., 2004, "The Triple-A Supply Chain," *Harvard Business Review*, (Oct), 2-12.

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