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THE COMPARISON BETWEEN "ETO" AND "NON-ETO" CAPABILITIES OF SUPPLY CHAINS IN TERMS OF THE CHARACTERISTICS OF MANUFACTURING ACTIVITIES

Abstract: From the perspective of a product development, employing ETO (engineer-to-order) and non-ETO (non engineer-to-order) concepts in the supply chains is contingent upon a number of factors reflecting the major characteristics of manufacturing practices. However, it may be assumed that there is a diverse intensity of the factors reflecting manufacturing features which enable to achieve and sustain the ETO and non-ETO capabilities of supply chains. The aim of the paper is to confront engineer-to-order and non engineer-to-order orientations of the supply chains in terms of their major appropriate characteristics of a manufacturing process. Having employed a research methodology and performed necessary statistical analyses, the conclusions were derived. They suggested to which extent the identified factors reflecting the properties of a manufacturing process may be referred to both ETO and non-ETO capabilities of the supply chains and how those factors distinguish between them.

Keywords: engineer-to-order, manufacturing characteristics, supply chain.

1. Introduction

The supply chain, which in the last few years has been a subject of intense research both in theoretical and practical frameworks, is currently one of the most dynamically developing concepts (Kisperska-Moroń, Świerczek 2009). On the basis of the literature review, Mentzer *et al.* (2001) quote more than 100 definitions of the notion "supply chain" which concentrate and regard its many different aspects. For the purpose of this paper the supply chain is defined as "a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances and information from a source to a customer" (Mentzer Ed. 2001).

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In order to survive and possibly increase a market share, the supply chains have to generate sales income from products which should meet specific customers' requirements. Therefore, it is necessary to identify different generic groupings of the products and connected services which fulfill specific customers' needs.

Customer requirements and their implications determine the organization of material flow of products in the supply chains. Firstly, the supply chains may deliver products from finished goods inventories as their production anticipates customers' orders; others, manufacture and deliver only in response to customers' orders. Those two situations are connected to different transactional standards of customer service, namely the customer's sensitivity to product availability and the ability of delivering unique products adjusted to the individual customer's requirements. In this connection, time and customization, are two distinct classification criteria of customers' needs. First criterion requires an emphasis on time which should not be wasted and is supported by fewer and faster activities being performed (Stalk 1998). On the other hand, customization means performing some activities according to the unique requirements of an individual customer (Wikner, Rudberg 2005).

One can notice a trade-off between a concentration on time and customization. The shorter time of expectation for the product, the less customized offering. On the contrary, the more individualized product, the longer lead time. Achieving a consensus between those two divergent variables requires an implementation of specific solutions in the organization of material flow of products, mainly depending on the identification of material decoupling point in a supply chain.

2. Defining "ETO" and "non-ETO" capabilities of supply chains through the location of material decoupling points

The length of lead time and the level of products' customization may decrease or increase gradually in the supply chains being determined by an appropriate location of material decoupling point. In the opinion of Hoekstra and Romme (1992) "the decoupling point is the point that indicates how deeply the customer order penetrates into the goods flow". The material decoupling point is a buffer between upstream and downstream partners in the supply chain. This enables them to be protected from fluctuating consumer buying behavior and therefore establishing smoother upstream dynamics, while downstream consumer demand is still met via a product pull from the buffer stock (Mason-Jones, Towill 1999).

In terms of the lead time and product customization, the location of material decoupling point is reflected in the most popular classification of manufacturing types, namely: engineer-to-order (ETO), make-to-order (MTO), assembly-to-order (ATO) and make-to-stock (MTO) (Naylor *et al.* 1999). The latter three may be called by a common notion of "non engineer-to-order" (non-ETO). This is parallel to the classification of Amaro *et al.* who proposed a taxonomy of make-to-stock and non make-to-stock organizations (Amaro *et al.* 1999).

In make-to-stock manufacturing products are standardized but not necessarily allocated to specific locations; the demand is anticipated to be stable or readily

forecasted at an aggregate level. In assemble-to-order system products can be customized within a range of possibilities, usually based upon a standard platform. Make-to-order is characterized by raw materials and components which are common but can be configured into a wide variety of products. In the last manufacturing system engineer-to-order products are specially designed from engineering specifications. While the products might use some standard components, at least some of the components or arrangements of components have been specifically designed by the customer or the customer working with the producer.

The decoupling point located in ETO ensures a high level of product individualization as customers would have the possibility to affect the manufacturing process at earlier stages or even at the stage of conceptual planning of a product (Blecker, Abdelkafi 2006). Simultaneously, employing an engineer-to-order approach denotes that the lead time is expected to lengthen. Moving the decoupling point according to non-ETO orientation results in manufacturing and delivering more standardized products and limiting the impact of customers on the extent of products' functionality, its appearance and other characteristics. In case of non-ETO approach one can also observe shortening of the lead time.

3. The characteristics of manufacturing process

Manufacturing companies differ in the way they meet demand for the products. In practice, there are many different types of manufacturing processes. Hayes and Wheelwright in their product-process matrix enumerate job shop (jumbled flow), batch, assembly line and continuous flow (Hayes, Wheelwright 1979). This evolution begins with a "fluid" process and proceeds toward increasing standardization, mechanization and automation. Those types of manufacturing posses a number of distinctive characteristics concerning both the external conditions of operating environment and the internal attributes of production processes.

Anderson and other authors argue that in the market conditions in which the company operates, there are several criteria that win orders against the competition, namely cost (price), product differentiation, amount produced, distribution, product and volume flexibility, delivery, innovation, quality, environmental and social responsibility (Strong 1997). An identification of the companies' competitive priorities should be the first step in a formulation of manufacturing strategy (Swink, Way 1995). This view is also supported by Hayes and Wheelwright who claim that the composition of competitive dimensions is a starting point in the formulation of the manufacturing strategy defined as "(…) a sequence of decisions that, over time, enables a business unit to achieve a desired manufacturing structure, infrastructure, and set of specific capabilities" (Hayes, Wheelwright 1984).

Among internal characteristics one can identify the following fundamental properties of a production process, namely: the degree of specialization and differences in the variety of products being produced, performance productivity of manufacturing practices, grouping of equipment (Williams *et al.* 1994), manufacturing process flexibility and a major resource used in a manufacturing process (Hill 1992).

Specialization refers to the breakdown of the total task into sub-tasks. From the perspective of production process, the four levels of specialization may be identified, namely: pure (producing a new design), tailored (modification to the existing design), standardized (selection from a set of designed options), none-standardized (take an existing design as it is) (Amaro *et al.* 1999). It is worth noting that specialization is tightly related to a product variety. The companies which produce complex products, especially products adjusted to the individual needs of customers, often modify their design. Many of these changes are formally initiated by the customer as new requirements, or by the company as modified specifications or manufacturing changes (Nadia *et al.* 2006).

The product structure should meet certain given criteria by combining a number of parts, features or functions required by the ultimate customers. From the technological point of view there are two generic types of product architectures, namely integrated architecture and modular architecture. In the case of modular architecture, each function is connected to a corresponding part, whilst in the case of integrated architecture; a part may have more than one function (Helo 2006). Apart from the requirements of customers, the structure of the final product determines the changes that might be carried out. The significance of the mismatch between market requirements and manufacturing process design and its impact on the performance of manufacturing companies was indicated by several authors (Berry, Hill 1992).

The performance dimension often linked to the manufacturing efficiency is productivity (Chew 1988) defined as the ratio of actual output to input over a period of time. Inputs might include transforming and transformed resources, such as staff and equipment. Outputs are goods and services (Slack *et al.* 2001). In its simplest form, labor productivity could be defined as the hours of work divided by the units of work accomplished (Thomas 1994). Another productivity dimension which have been studied for several decades is the productivity of manufacturing facilities. It is a metric used for measuring and analyzing the productivity of individual production equipment in a factory. Equipment productivity metric assess an internal efficiency and it is a measure of the value added in a manufacturing process by an equipment (Johnson, Lesshammer 1999).

Another important characteristics is grouping of the equipment which refers to the way of combining specialized activities on both physical and organizational bases. The criteria of grouping are a similarity of production equipment (grouping by machine type), and alternatively, units rationalized around a common task that is, grouping by product.

Grouping the machines by product allows to decentralize production into manufacturing cells, which are the essence of flow shop "islets" in a job shop environment. By grouping the machines into clusters and the various parts into part families, the processing of each part family is allocated to a single machine cluster (Cheng 1992). The adoption of a cellular layout is associated with reductions in performance obstacles in material delivery, the availability of resources and the quality of work information (Brown, Mitchell 1991). Implementation of cellular manufacturing also allows to reduce manufacturing throughput and setup time (Ghosh 1990) because each product is manufactured wholly or largely in one area.

The other characteristics is manufacturing flexibility which can be grouped into four types, namely new product flexibility (related to the system's ability to introduce different products or modify existing ones), mix flexibility (related to the system's ability to manufacture a broad range of products within a given period of time), volume flexibility (related to the system's ability to change its aggregated level of output), and delivery flexibility (related to the ability of the system to change delivery dates). The level of manufacturing process flexibility is partly determined by a complexity of BOM (Bill of Materials).

In the opinion of Chen and Wang "the generic BOM provides an efficient way to describe a large number of variants with limited amount of data" (Chen, Wan 2007). BOM complexity reflects the number of levels in the bill of material and the typical number of items on each level (Wanstrom, Jonsson 2006). It influences the number of parent and neighbor items (Ho, Li 1997). It may be assumed that the greater BOM complexity, the higher probability of manufacturing process flexibility.

More recently, the resource-based perspective has been applied to the issues of manufacturing process. In general resources are assets which a firm possesses, controls or to which it has its access. There many diverse criteria of resource classification. One of the mostly cited distinguish between infrastructural and structural resources.

Hill defines infrastructural resources as the set of structures, controls, procedures, systems and communication combined with attitudes, experience and skills of the people involved with the manufacturing system and structural resources as the technology, equipments and facilities of the manufacturing system (Hill 1989). In the opinion of Slack the resources can be classified into three generic groups, namely technological resources – the facilities and technology, or the hardware side of the manufacturing system, human resources – people in the manufacturing system, infrastructural resources – the systems, relationships and information couplings which bind the operation together (Slack 1989).

4. Data collection, propositions and research methods

The main research instrument used for this study was a questionnaire developed by the Global Manufacturing Research Group consisting of several sections examining manufacturing practices. There is no single meta-theory for guiding a development of GMRG survey. Instead, many aspects of general manufacturing practices were a subject of investigation.

Data collected within a fourth release of a survey has been collected by researchers from several countries in Europe, North America, Asia and Africa. For the purpose of the research presented in this paper only a portion of selected variables has been used. Originally 25 (23 independent and 2 dependent variables) were a subject of initial analysis.

The total sample employed for this research consisted originally of 861 manufacturers. As a result of initial data analysis, screening and elimination of observations with missing values 489 companies remained as a subject of further analysis.

On the basis of the literature review and in order to realize an empirical aim of the study, two research propositions have been postulated:

P1: There are the major factors differentiating manufacturing activities performed in the supply chains,

P2: There are the differences between ETO and non-ETO capabilities of the supply chains in terms of the major factors reflecting specific properties of manufacturing process.

In order to investigate research propositions a two-step statistical analysis was employed. The first step was the reduction of the 23 independent variables through factor analysis in order to highlight the main underlying multi-item factors reflecting attribute of production process. In order to perform the factor analysis a Principal Component Analysis (PCA) with Varimax Rotation was employed. PCA was performed to structure the collected information and the Varimax Rotation was employed to reduce multicollinearity among variables. The analysis was conducted on standardized variables.

The inspection of anti-image correlation matrix has led to the elimination of 4 variables whose a measure of individual sampling adequacy was below a nominal cut off point of 0.5. In the result of factor analysis 1 variable was excluded as it indicated factor loading below a nominal cut-off point of 0.6. Finally, factor analysis which was carried out on 18 items, enabled to identify the following set of constructs (Tab. 1):

Factor 1: Order winning criteria (cost, quality, delivery, product variety, environmental safety),

Factor 2: Productivity (manufacturing cost index, labor productivity, equipment productivity),

Factor 3: Flexibility (flexibility to change output volume, flexibility to change product mix, number of items on the Bill of Materials),

Factor 4: Grouping of equipment (by machine type , by product or product families),

Factor 5: Level of manufacturing specialization (% of one of a kind, of large batch),

Factor 6: Resource orientation (labor, material),

Factor 7: Products' variety (number of manufactured product lines or product families).

The number of factors was determined according to the analysis of the percentage of variance explained and the Kaiser criterion (Aczel 1993). KMO coefficient score indicating a suitability of the sample for factor analysis in a space of 21 variables is 0.877 which is a very good result (Bryman, Cramer 1999). Bartlett's test of sphericity demonstrated sufficiently high value for the extracted factors at $p <= 0.000$ (approx. chi-square 5108.9, $df = 210$).

As shown in Table 1, the obtained factors explain above 65% of total variance. The Cronbach's alpha coefficients were calculated to check the internal consistency of extracted factors. Alpha score of transformed variables in all instances is above the nominal cut-off point of 0.6. Considering the rule provided by D. George and P. Mallery, the obtained results of alpha coefficients suggest a good internal consistency of those three extracted constructs (George, Mallery 2002). The second step of the study was the classification of the sample into homogenous groups through cluster analysis. The criteria for classifying the sample into clusters were the seven factors extracted in the previous step.

Table 1. *The structure of the constructs obtained through the factor analysis*

Variables	**Factors**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Share of labor cost in manufacturing cost						–0.761	
Share of material cost in manufacturing cost						0.738	
Cost (price)	0.630						
Quality (conformance to specifications)	0.687						
Delivery timeliness	0.799						
Product variety	0.807						
Environment/safety	0.868						
Number of items on typical Bill of Materials		0.643					
Flexibility to change output volume			0.881				
Flexibility to change product mix			0.860				
Labor productivity		0.909					
Equipment productivity		0.835					
Manufacturing cost index		0.778					
Percent of one of a kind products					0.828		
Percent of large batch products					–0.767		
Number of manufactured product lines							0.926
Equipment grouped by machine type				–0.778			
Equipment grouped by products				0.818			
Eigenvalue	2.821	2.177	1.971	1.573	1.355	1.163	1.026
Percent of total variance explained	15.18	12.04	11.03	8.46	7.53	6.93	5.95
Cumulative percent variance explained	15.18	27.22	38.25	46.72	54.25	61.18	67.14

At first in order to determine the number of clusters a hierarchical cluster analysis with Ward's partitioning method and squared Euclidean distance was performed (Sagan 2003). In the result of the analysis four clusters were formed. The number of groups was obtained through the greatest increase in the agglomeration coefficient while minimizing a number of clusters (Ketchen, Shook 1996).

The greatest increase corresponds to the grouping of all cases from four to three clusters. The number of four clusters was used to perform K-Means Cluster Analysis to assign each case to the appropriate cluster. The criterion of the cluster membership was the minimal Euclidean distance between each case and classification center represented by centroid. The results of K-Means Cluster Analysis was compared with the class assignment obtained from the Hierarchical Cluster Analysis. On the basis of the results of two partition methods the contingency table was constructed and Rand Index calculated. The measure of agreement showed that 77% of pairs of objects are placed in the same class. It means a sufficient level of agreement and confirms a correct choice of K-Means Cluster Analysis as the leading clustering method (Krieger, Green 1999).

5. Data analysis and discussion

In the result of cluster analysis two diverse types of clusters may be identified. First type includes one cluster with a prevailing share of companies employing an engineer-to-order concept. The second type of clusters accounts for three groups of companies which mostly apply make-to-order, assembly-to-order and make-to-stock orientation. Therefore, the first type of clusters can be described as "ETO cluster" and the second one can be characterized as "non-ETO clusters".

The "ETO cluster" consists of 135 companies, which represent 28% of the whole sample. Most cases in the class are companies from Fiji and USA. The companies operate mostly in three industries, namely food and kindred products, chemicals and electronic sector. The analysis of the major properties of manufacturing practices reveals that the companies in the first cluster indicate a high level of flexibility in the process of adjusting of the products and their variants to the customers' requirements. The companies in the cluster perceive a labor as an important resource in their activity, and deliver "one of a kind" products. The firms in the first group are characterized by a lower level of productivity and their manufacturing equipment is grouped by a product or product families. The obtained results suggest a high level of consistency between manufacturing properties of companies from the cluster with a degree of product customization indicated by ETO capability.

The joint group of three non ETO clusters includes 354 companies, which constitutes 72% of the sample. The companies from this group originate mostly from Poland, USA, China and Shanghai, Hungary, Italy. The class is a combination of companies producing fabricated metal products, industrial and commercial machinery, electronic equipment. Considering the characteristics of manufacturing activities, it is worth noting that the companies indicate a moderate or lowest level of flexibility and the highest degree of productivity. Firms from this group manufacture the products mainly in large batches, on the mass-scale. The companies also appear to place a greater emphasis on material-oriented approach and infrastructure assets. They mostly group the equipment by machine type or assembly line.

Table 2 presents the comparison of manufacturing characteristics for both ETO and non-ETO capabilities of supply chains.

Table 2. *Importance of manufacturing characteristics for ETO and non-ETO capabilities*

	Order winning criteria	Productivity	Flexibility	Grouping of equipment	Level of manufacturing specialization	Resource orientation	Products' variety
ETO cluster	similar	low level	high	product	important	important/ labor	high level
non-ETO cluster	similar	high level	moderate	very important	less important	important/ material	low level

The analysis of clustering reveals that the companies from "non-ETO clusters" indicate a lower level of product customization in the supply chains and a relatively large share of products to be assembled to order and make to stock. This non engineer-to-order orientation is followed by major characteristics of the performed manufacturing process leading to manufacturing and delivering more standardized products in a shorter lead time. It should be noted that "non-ETO cluster" is internally diverse which may suggest there are many ways to achieve and sustain specific kinds of non engineer-to-order capabilities.

The above results of the analysis may prove that an application of ETO and non-ETO capabilities of a supply chain requires a specific combination of the properties of manufacturing process. In general, the analysis proves that there is a high level of consistency between described capabilities of the supply chains and intensity of manufacturing features. Achieving specific characteristics supports and enables implementation of the appropriate capabilities of the supply chains.

Therefore, the empirical study may confirm the first research proposition which suggests that there is a set of major factors differentiating manufacturing activities performed in the supply chains. This group embraces the following factors: order winning criteria, productivity, flexibility, grouping of equipment, level of manufacturing specialization, resource orientation and products' variety.

The comparison of "ETO group" and "non-ETO clusters" in terms of their properties of manufacturing process provides some interesting insights. The "ETO cluster" is more focused on manufacturing and delivering customized products in order to meet changing customer demand. The companies from this group apply soft resources (concentration on labor, higher level of labor productivity) and achieve a higher flexibility. They group their manufacturing equipment around a specific task by a product or product families. As the companies from "ETO cluster" do not provide products on a large scale, their indices of productivity are lower, as compared to the "non-ETO group". The latter cluster is more concentrated on delivering products in a large batches, less individualized, more standardized and common. The firms from the "non-ETO cluster" are more concentrated on hard resources such as materials and infrastructure assets. They are also less flexible and their manufacturing equipment is grouped by machine type or assembly line. Those conclusions may confirm the second research proposition suggesting that there are the differences between ETO and non-ETO capabilities of the supply chains in terms of the major factors reflecting specific properties of manufacturing process.

6. Future directions of further research

This empirical study, apart from providing some insights into the comparison between ETO and non-ETO capabilities of supply chains in terms of manufacturing practices, also highlights some areas of future research. An important element is employing of a wider scope of research considering, apart from manufacturing, also logistics, marketing and finical issues. What requires further investigation is also a more in-depth study of the characteristics of manufacturing practices not restricted to ETO and non-ETO but regarding a detailed analysis of the ETO, MTO, ATO and MTS capabilities. Next issue which needs to be examined is the empirical analysis of the alignment of ETO and non-ETO capabilities with the key success factors maximizing competitiveness of the supply chains.

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