VOL. 11, NO. 1, JANUARY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

FACTORS OF TECHNOLOGY SELECTION AFFECTING THE CONFIGURATION OF SUPPLY CHAINS IN INNOVATIVE INDUSTRIES: A SURVEY OF UK COMPANIES IN THE COMPOSITES INDUSTRY

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ABSTRACT

The configuration of the supply chain is one of the main challenges faced by organizations operating in young, dynamic industries characterized for the use of new materials and technological innovations. In composites materials, a young developing industry, there is not a neither standard manufacturing process, nor are there standardized materials with defined or proscribed properties for companies to select. Using a survey of companies in the UK's composites material industry this research investigates 19 factors related to technology selection in manufacturing and supply chain configuration. The analysis performed includes descriptive statistics and correlation tests. The results for factors influencing manufacturing technology selection shows that improvement of quality and reduction of inventory levels received the highest and lowest average rates respectively. Regarding supply chain configuration, selection of the right manufacturing technology showed the highest average rate followed by on time deliveries/service level to customers. The responses are not conclusive yet indicative of some trends the composites materials industry in the UK needs to address as some important factors affect the configuration of their supply chain.

Keywords: supply chain management, technology selection, innovative industries, composites materials, UK.

INTRODUCTION

The development of new products and applications based on new materials and technological innovations offers great business opportunities but also numerous challenges. The composites materials/carbon fiber is an industry that has been experiencing substantial growth because of new products and technological applications developed in recent times. Around the world the composites materials industry is growing steadily in many locations, as the expected global demand for carbon fiber will grow from 46,000 tons in 2011 to 140,000 tons by 2020 with production capacity being increased from 102,000 tons in 2011 to 129,000 tons in 2015, with the potential for further growth to 185,000 tons by 2020 [1].

Polymer matrix composites (PMCs), also known as fiber reinforced polymers (FRPs), consist of a matrix material, which is a polymer based resin, surrounding and supporting a reinforcement of some kind (typically fibers, particles or flakes). The resultant PMC has properties that are advantageous compared to those of either the matrix or the reinforcement when used on their own [2]. Recent numbers show the global composite materials market value is estimated at USD $23.9 billion in 2013 and expecting to reach USD $35.2 billion by 2019 [3]. In such context, inevitably many companies in the composites materials sector face the challenge of how to configure the supply chain to support the demand for resins and fibers, semi-finished materials, components and structures used in some of the most advanced and innovative solutions for the aerospace, automotive, construction, medical equipment, marine, oil and gas, rail and renewables sectors including wind energy.

The study of the supply chain of composites materials is a growing field as sectors such aerospace representing a global market of $4,471 bn continue to expand the adoption of structures and components made of composite materials. Other sectors such as automotive has seen an increase in the use of composite materials as there is need to lightweight vehicle structures in order to meet new legislation regarding emission reduction. Benefits of composite materials to automotive applications include reduced number of parts, reduction in tooling costs, good corrosion resistance and excellent crashworthiness properties among others [2].

The next sections of this paper cover the literature review on the identification of factors affecting technology selection in manufacturing and the configuration of the supply chain. The methodology section comprises the utilization of a survey of UK-based companies in the composites materials sector in order to rate the importance of 19 factors. The responses to the survey are analyzed in order to identify trends and important aspects that affect the UK's composites materials industry.

LITERATURE REVIEW

Technology selection plays a fundamental role in the operations of today's manufacturing and supply chains as there can be multiple benefits that can be achieved. Technologies and strategies affecting manufacturing

operations result in better competitiveness and improvement programmes [4]. Technology selection has a fundamental role in the configuration of the supply chain, as opportunities and threats are normally associated with a technology alternative in the supply chain context [5]. Technology represents a key variable for identifying competitive policies, production strategy, innovations, creativity and commercialization activities among others [6].

One important aspect of technology selection is that it can have multiple ramifications and can be assessed in various ways. In fact, it is possible to find technology is mostly assessed in terms of financial benefits; however, these models have been subject to criticism over time [5]. In [5] it is possible to find technology selection models should address shortcomings that include aspects such as: a) the technology selection processes fail to incorporate risk calculations in strategic technology selection; b) the threats associated with a technology alternative have not been considered in the technology selection process and their importance in technology evaluation is neglected; and c) lack of support for the inclusion of inter-organizational factors in the technology selection decision making environment.

In [7] there is a discussion about a framework that combines supply chain and manufacturing together. Among the elements included in the framework presented in [7] are the evaluation of current supply chain, identification of critical supply chain factors, planning range, identification of manufacturing technologies, detailed assessment of identified technologies and risk assessment of technology alternatives.

It is important to emphasize that technology selection has close links with supplier selection because of its strategic implications for design/planning in the supply chain. In [8] the authors reviewed the literature on supply partner selection decision-making published between 2001 and 2011 using a classification framework developed by [9] and based on [10]. In [7] the authors recognize that the use of [10] formulation of criteria, qualification, final selection and application feedback allows for an effective means of solving highly complex problems.

The rating of technology-related factors is important as new technologies and new technological developments continue to affect the performance of manufacturing and the supply chain. For example, in the case of new technological developments such as cloud computing, the work found in [11] highlights that cloud computing, as an emerging technology, is changing the form and function of information technology infrastructures and spreading within the supply chain. Using an analogy we can say composites materials represent a new technology that is changing manufacturing operations and opening the doors for the creation of new products and spreading within the supply chain.

Factors affecting manufacturing technology and supply chain configuration can impact decision-support making processes. Moreover, the development of decision-making support tools in supply chain management has received significant attention in recent years. The development of decision-support tools that can assist organizations in the design and configuration of their supply chain is particularly important in young industries experiencing high levels of uncertainty. It has long been acknowledged that change and uncertainty in business environments are primary causes of great loss in manufacturing industries [12, 13].

The factors related to technology selection in manufacturing and supply chain configuration are shown in Table-1. These factors were tested in a survey targeting the UK's composites materials industry. The particularities of the composites materials supply chain are explained in the following section.

PARTICULARITIES OF THE COMPOSITES SUPPLY CHAIN

Companies in the manufacturing industry are collaborating with suppliers and customers to achieve seamless integration of manufacturing and supply chains [5]. A review of the traditional definition of supply chain management remind us about the creation of value by reaching beyond the traditional borders of a firm including suppliers, customers and other stakeholders [14]. Businesses in all sectors will agree that supply chain management integrates ''key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders'' [15].

Table-1. List of factors of technology selection related to manufacturing and supply chain configuration.

Reduce cycle time
Improve quality
Reduce labor costs
Reduce scrap and rework
Increase capacity
Increase market share
Reduce inventory levels
Technology used by our suppliers
Technology used by our customers
Automation
Rapid manufacturing/prototyping
Capacity sizing and high volumes manufacturing
Reduce supply chain cycle time
Low cost manufacturing
Return on investment
Supply chain performance
On-time deliveries/service level to customer
Hire/train staff with new skills
Reduce environmental impact

Technology innovative industries like composites materials require a clear understanding of the various echelons/stages that comprise the supply chain. Figure-1 depicts the simple structure of the composites materials supply chain.

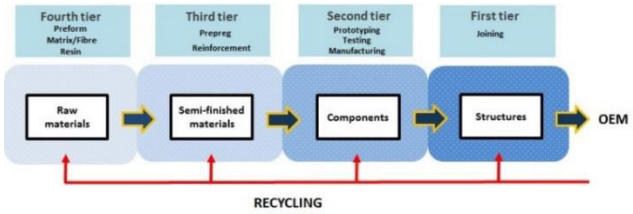

Figure-1. Diagrammatic representation of the composite materials supply chain.

In Figure-1, raw materials cover the supply of resins, fibers and core materials. Semi-finished materials cover the materials that go through processes such as 'prepreg' (pre-impregnated composite fibers). Components refer to the development and manufacture of composite material parts. Structures refer to the manufacture of composite systems by joining several components. At the end of the chain there are OEMs who manufacture end products that can include from planes, to cars, to furniture used in railway stations, sports gear, medical equipment and many more.

METHODOLOGY

A survey was designed to obtain data regarding companies rating 19 factors related to selecting manufacturing technologies and selecting manufacturing technology with respect to the supply chain. The structure of the questionnaire covers the following details:

- Company details, UK sites, length of operation, turnover, number of employees, etc.
- The structure and size of the company's supply chain including:
  - Company position in the supply chain.
  - Number and types of links up and down the supply chain.
- Manufacturing processes currently used, use of recycled materials
- Market areas the company currently supply to and/or plan to supply to.
- Rate the importance of seven factors in selecting manufacturing technology in a 1 to 5 scale (cycle, time, quality, labour cost, scrap and rework, capacity, market share and inventory).
- Rate the importance of twelve factors in selecting manufacturing technology with respect to your supply chain (right manufacturing technology, the technology used by your suppliers, the technology used by your customers, automation, rapid manufacturing, capacity sizing and high volume production, supply chain cycle time, low cost manufacturing, return on investment, supply chain performance, on time deliveries/service level and hiring/training staff with new skills).

The questionnaire comprises the factors identified in [5] where a technology selection framework integrates manufacturing within a supply chain. We can highlight from the structure mentioned above that the first section of the questionnaire aims to capture general information of the companies such as age of business in the composites sector, turnover, etc. The second section is related with the supply chain structure and the position in the UK composites supply chain as indicated in Figure-1. Finally, in the third and fourth section, the companies were asked to rate seven and twelve factors in selecting manufacturing technology and selecting manufacturing technology with respect to their supply chain respectively. Respondents to the questionnaire used a five-point Likert scale (5 for very important to 1 for unimportant) to rate the importance of each of the 19 factors identified. The companies contacted to participate in this survey are members of the Composites UK Trade Association. The list includes just over 300 members. The questionnaire was distributed via email to each of the members of Composites UK Trade Association. A copy of the questionnaire can be found in: https://rhulsom.eu.qualtrics.com/SE/?SID=SV_3UXBdalLkAxU0Nn.

RESULTS

The total of responses received from the surveyed companies represented about 18% of the members of the Composites UK Trade Association. Responses were collected during the first months of 2015. In total 46 valid answers were returned. General statistics about the responding companies showed aspect regarding age of business (30.2% of the sampled companies have been in composites less than 10 year, 35.8% between 10 and 20 years and 34% more than 20 years, there were 2 missing answers). So these results show that newcomers to the industry represent a minority. The results of the survey show that companies have turnovers typical of small-medium enterprises (68.2% of the sample has a turnover lower than £10,000,000 with 11 missing answer).

Composites materials have been labelled as a young, growing sector with characteristics of a high-tech industry. According to the definition provided by the OECD [16] high-tech industries devote on average more than 10% of their expenditures to R and D. The results of the survey shows that about 31.4% of the companies that participated in the survey have a R and D expenditure of 10% or more. Figure-2 shows a pie chart with the results of the respondents' primary position in the supply chain.

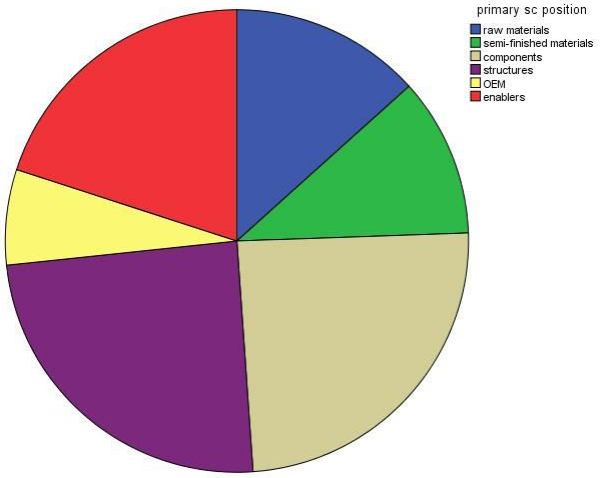

Figure-2. Primary position in the composites supply chain by the respondent companies.

In Figure-2 about a quarter of the companies identified themselves as structures or components manufacturers, followed by raw materials and semi-finished materials. A significant number of companies identified themselves as enablers but only a few as OEMs.

The answers that the surveyed companies gave to the question about the primary market served are depicted in Figure-3.

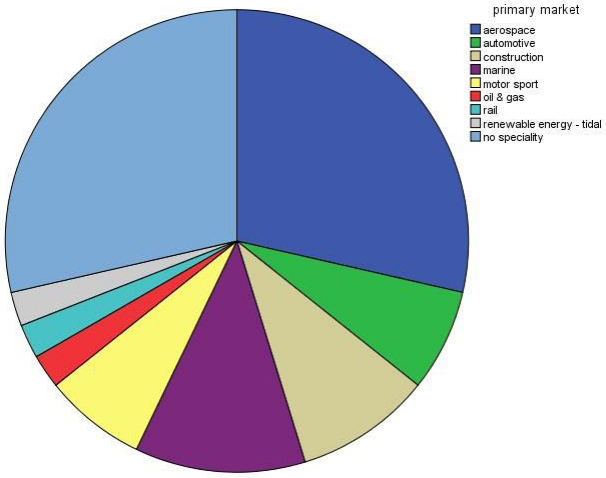

Figure-3. Primary markets served by the respondent companies.

The results of Figure-3 show that about 28.6% of surveyed companies answered they do not have a speciality market (with 5 missing answers). That was followed by companies who serve the aerospace sector, construction, marine, automotive, motorsport, oil and gas, rail and renewable energy - tidal.

TECHNOLOGY SELECTION

In this section the companies were asked to rate the importance of seven factors in selecting manufacturing technology in a 1 to 5 scale (5 for very important to 1 for unimportant). These factors include cycle, time, quality, labour cost, scrap and rework capacity, market share and inventory. Figure-4 shows the results of the rates given to the factors associated to technology selection. The respondents gave improve quality the highest rating, followed by reduce cycle time, reduce labor cost, reduce scrap and rework, increase capacity and increase market share. Reduction of inventory levels received the lowest rating by the surveyed companies.

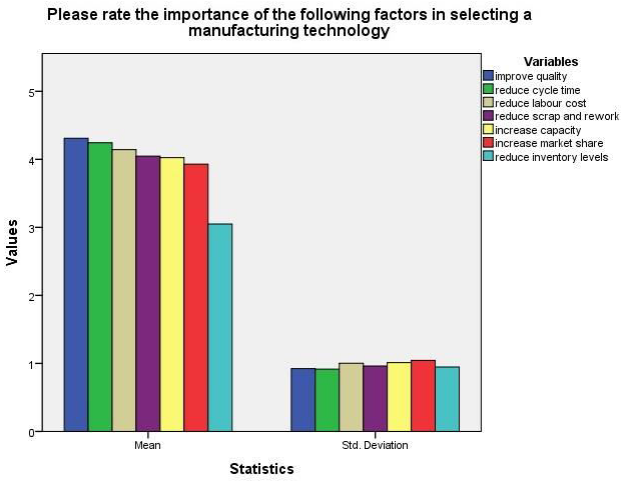

Figure-4. Responses to factors related to selecting manufacturing technology.

Two key points can be highlighted about the responses to the factors related to selecting manufacturing technology:

- All the factors have received an average rate equal or higher than 3 (moderately important).
- Improve quality and reduce inventory levels have received the highest and lowest average rates respectively.

TECHNOLOGY SELECTION WITH RESPECT TO SUPPLY CHAIN

In this section the companies were asked to rate the importance of twelve factors indicated in the questionnaire which relate to selecting manufacturing technology with respect to the company's supply chain in a 1 to 5 scale. In total 46 valid answers were returned. The results of the twelve factors are shown in Figure-5. The results of the survey show that respondents rated higher factors related to making the right choice of technology, good performance of the supply chain and return on investment. Traditional performance measures such as

capacity management, cycle times and rapid prototyping received low scores.

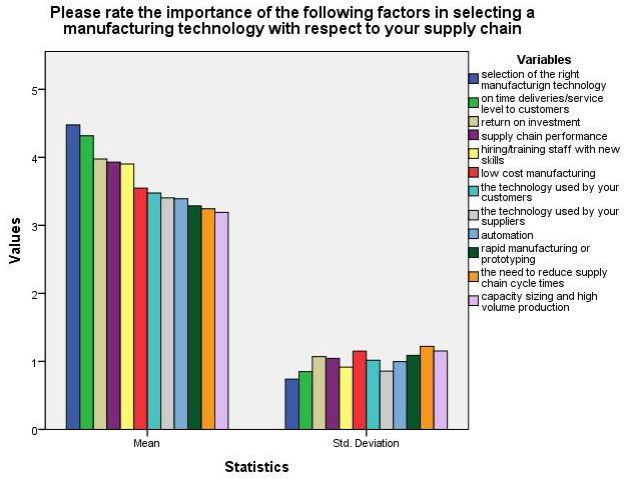

Figure-5. Responses to factors related to selecting manufacturing technology with respect to the supply chain.

Three key points can be highlighted about the responses to the factors related to selecting manufacturing technology with respect to the supply chain:

- All the factors have received an average rate higher than 3 (moderately important).
- Selection of the right manufacturing technology show the highest average rate followed by on time deliveries/service level to customers.
- Rapid manufacturing/prototyping has surprisingly received the lowest average rate.

There is no doubt the composites materials industry has been experiencing remarkable growth in recent years. The responses received to the above factors reveal that companies in this industry in the UK still possess the characteristics of organizations operating in niche markets. This is represented by the high rates given to the selection of right manufacturing technology, service level and return on investment. As the industry continues to develop and increases its volume output it will be possible to see higher rates to factors like rapid manufacturing/prototyping.

A correlation analysis at the 0.01 level of confidence (2-tailed) was performed on the data collected. The analysis performed revealed correlation between several factors. The factor reduce scrap and rework presented strong correlation with improving quality, hiring/training staff with new skills, reduce cycle time, selecting the right manufacturing technology, increase market share, reduce labour cost and supply chain performance, seven in total. The factor improve quality shows correlation with four factors including reduction of inventory levels, reduce cycle times, selecting the right manufacturing technology, reduce scrap and rework and hiring/training staff with new skills. On the other hand, three factors including the technology used by your suppliers, the technology used by customers and rapid manufacturing and prototyping did not show correlation with other factors.

Few strong correlations at the 0.01 level of confidence (2-tailed) were found between company details and factors tested. The results reveal strong correlation between years of business in composites and the factor hiring/training staff with new skills.

CONCLUSIONS

The composite materials sector is a key supplier to other "high-tech" sectors such as aerospace, automotive, construction, marine, oil and gas, rail, sports gear, medical equipment and renewable energy among other sectors. Given the growing importance of composites materials to large industries, it has become imperative to identify factors that affect the selection of technologies in manufacturing and in the configuration of the supply chain.

Technology selection exerts great influence on the configuration of supply chains and the composites materials industry is no exception. The main contribution of this research is that it explores how companies in the composite materials industry rate some critical factors related to the selection of manufacturing technology with respect to the supply chain. The analysis of the responses shows that the selection of the right manufacturing technology is a key factor with respect to the supply chain. Companies in the composite sector consider cycle time and quality as fundamental factors for selecting a manufacturing technology, while inventory received the lowest ratings. From a supply chain perspective, service level demonstrated to be the most important factor when it comes to select a manufacturing technology.

An industry survey comprising other locations outside the UK will help to extend the views of the industry regarding the factors presented in this paper and how that affects the supply chain. A wider investigation involving a large pool of companies in the composites materials industry, perhaps at the European level, will help to confirm and extend the findings. Finally, the results of this research may be used to develop future frameworks that can help companies in the composites materials select a manufacturing technology and configure their supply chain.

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