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An Empirical Analysis of the Factors That Support the Drivers of Sustainable Manufacturing

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Abstract

Manufacturing businesses have been contributing to energy consumption, pollution and resources consumption. Alongside governmental legislations, there are many drivers of Sustainable Manufacturing such as social and market pressures which are growing as awareness about environmental issues increases. These drivers have been extensively researched as evidenced in the literature. However, this study goes beyond the drivers themselves to unveil the factors that underlay each driver. For example, customer demand is a driver that depends on factors such as the importance of environmentally-friendly products to win orders and the bargaining power of customers. Thorough understanding of these factors will provide the knowledge economy with the information required to advance manufacturing and the environment. In this study we analyzed ten factors that underlay the drivers: Market pressure, Competitiveness and Supply Chain pressure. Using data collected from 36 manufacturing companies, factors were ranked based on their importance. The results show the ranking of ten factors. Further analysis of the factors revealed some interesting characteristics of Sustainable Manufacturing.

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Keywords: Sustainable Manufacturing; Drivers; Environmental Sustainability; Lean; Six Sigma

1. Introduction

Efforts to reduce the impact on the environment have been increasing in the last decades as awareness of environmental issues extended beyond the scientific community and into the public domain. Politicians now regard environmental sustainability as a priority and use governments' power to impose it. The manufacturing industry is particularly responsible as the most energy consuming industry and because of its waste and emissions [1-2]. A lot of research has been conducted to explore the requirements for manufacturers to become sustainable. Kashmanian et al. [3] identified these requirements and classified them into stages that a company progresses through to transform to an environmentally sustainable company. During this transformation, some drivers play an important role in enabling manufacturers to integrate environmentally friendly practices in their management system, while at the same time, other factors hinder the transformation process and act as barriers to change. This study reviews the literature to identify the significant drivers for the environmental side of sustainable manufacturing and then uses data collected from 36 manufacturing companies based in the UK to analyze the factors that make up some of these drivers.

2. Literature Review

Research on the drivers of Sustainable Manufacturing (SM) has been very active in the last two decades. The most influential driver prior and during the 1990s was governmental regulations [4]. However, as companies started to look beyond legal requirements for various reasons, such as pressure by non-governmental bodies, cost savings and customer demand, the strategy of these companies shifted

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from being merely in compliance to beyond compliance; beyond fence line; and beyond footprint [3]. As a result, research in this area has grown rapidly to cover in greater details the influence of various drivers that facilitate the pursuit of better environmental performance.

A study by Mittal and Sangwan [5] into the drivers of SM supports the view that the importance of drivers is changing. They developed a fuzzy TOPSIS method to rank 13 drivers and concluded that four drivers are the most important for adopting SM, these are; 'Competitiveness' between companies; 'Incentives' given by governments; 'Organisational resources' and 'Technology'. Table 1 shows the drivers in their ranking order and some examples. However, ranking the drivers depends on the type of industry, region and the maturity of the market. For example, Zhu et al. [6] found that the most important drivers for the Chinese Automotive Industry were regulatory requirements and market pressure. Therefore, this study takes a different approach to the evaluation of SM drivers, by considering the factors that underlay these drivers.

The success of SM depends on the above mentioned drivers, and these drivers in turn depend on factors that determine the strength of each driver. For example, the driver 'Supply chain pressure' depends on factors such as the 'Bargaining power of suppliers', the 'Level of supply chain integration' and others. The review of the literature on SM did not produce a single study analyzing these factors. The authors acknowledge that the data available from the survey is limited and allows only for the study of few factors that support some drivers. The following is a review of the drivers we aim to study and their underlying factors.

2.1. Supply Chain Pressure

In the area of Green Supply Chain Management (GSCM), the drivers to change are similar to those found in single manufacturing companies. Walker et al. [7] found that studies of GSCs tend to focus on drivers rather than barriers due to the desire to focus on positive aspects of GSC research. They also found that large organisations, in the private and public sectors, are likely to hold the power to influence the suppliers to respond to the environmental agenda. This makes the size of a company a very important underlying factor for the driver 'Supply chain pressure' and, indeed, an important underlying factor of other drivers.

Another important factor is the 'level of supply chain integration'. Growing evidence suggest that the higher the level of supply chain integration with suppliers and customers the greater the potential benefits [8].

In addition to the above mentioned factors, the 'bargaining power of suppliers' is very important in increasing, or decreasing, the pressure of the supply chain to adopt SM.

2.2. Market Pressure

Zhu et al. [6] used the term Market Pressure in their research to cover market related drivers such as 'Customer demand', 'Peer pressure' and 'Public image'. The market associated with environmentally-friendly products has been researched for more than a quarter of a century. Welford and Gouldson [9] reported that in the year 1990 the size of the market for "environmental improvements" was estimated at $200 billion worldwide and expected to grow rapidly. In 2011, in the UK alone, the green goods and services sector was worth £122 billion [10].

The findings of the Global Corporate Social Responsibility (CSR) study [11] illustrate that there is a rapid shift in global markets towards environmental products and activities. The study covered more than 10,000 citizens from 10 of the largest countries by gross domestic product (GDP). An important finding of the study is that customer awareness of social and environmental issues is a significant cause of this change. An important accelerator of this awareness is social media where bad or good news about a company could change its reputation and consequently its market share.

On a global level, the CSR study found that more people tend to shop for products and services that provide social and environmental benefits. In addition, consumers use their purchasing power to protest against irresponsible products. Nine out of ten global participants would boycott a company if they learned of its irresponsible practices. In fact, more than half (55%) have done so in the past 12 months according to the same report. The factors available for us to study the driver of 'Market pressure' are: 'Market competition' and 'Market concentration'. The two factors differ in nature as in some markets the competition is fierce even if the number of competing companies is small. Markets of new technologies are an example of this type of markets. Whereas in other markets, a large number of companies may work in a low competition environment.

The 'Bargaining power of customers' and the 'Importance of environmentally-friendly products to win orders' are also factors that affect the driver 'Market pressure'. Customers such as large companies and government units in countries that tackle climate change, strongly demand for products and services of low ecological impact [1].

2.3. Competitiveness

Making most out of resources is an important approach to win competition. Manufacturing companies learned a key lesson from the Japanese car maker Toyota as the company practiced its Toyota Production System, also known as Lean Manufacturing, to achieve better process performances, higher product quality and higher efficiency, which are the underlying factors that support the driver 'Competitiveness'. Moreover, Lean Manufacturing provides a strong base for SM as it reduces the consumption of resources and wastes [12].

Six Sigma is another important management system that has been adopted very successfully in the manufacturing industry. Similar to Lean Manufacturing, Six Sigma improves quality, delivery time and flexibility to promote competitiveness. Lean and Six Sigma, therefore, are considered in this study as factors supporting the driver 'Competitiveness'.

Table 1. Drivers of SM with some examples and the factors under study (adapted from [6]).

Drivers	Cases	Supporting Factors under study	Rank
Competitiveness	(Better process performances, higher product quality, higher efficiency, competing with best practices in sector, etc.)	Lean Manufacturing, Six Sigma.	1
Incentives	(Investment subsidies, awards, R&D support, tax exemptions, duty free imports, etc.)		2
Organizational resources	(Availability of financial resources and skilled staff to implement programs.)	Annual spending on environmental programs	3
Technology	(Opportunities, advantages and performance of available green and efficient technology)		4
Cost savings	(Reduction of energy consumption, reduction in virgin material use, less waste, etc.)		5
Top management commitment	(Management, owner or investors are highly committed to enhance environmental performance, ethics, social values, etc.)		6
Customer demand	(Demand for environmentally friendly products)	Market competition, market concentration, importance of env.-friendly products to win orders, bargaining power of customers	7
Supply chain pressure	(Demand by suppliers, distributors, OEM, compliance with legislation in global markets)	Level of supply chain integration, bargaining power of suppliers	8
Public image	(Importance of a positive public perception of company, green image, etc.)		9
Future legislation	(Expected development of stricter laws, increased level of enforcement.)		10
Current legislation	(Pollution control norms, landfill taxes, emission trading, polluted water discharge norms, eco-label, etc.)		11
Public pressure	(Local communities, politicians, NGOs, media, insurance companies, banks, etc.)		12
Peer pressure	(Trade and business associations, networks, experts, etc.)		13

3. Research Methodology

3.1. Questionnaire Design

The empirical data used in this study consists of questionnaire responses from manufacturing businesses based in the UK. The primary goal of the questionnaire was to develop a conceptual framework to improve the sustainability of manufacturing businesses [13]. The questionnaire covered four sections: (i) Market Conditions, (ii) Development Investments, (iii) Operations management and (iv) Environmental Practices. Questions for the first and third sections were developed based on items used in the International Manufacturing Strategy Survey (IMSS) [14] using a five-point Likert-scale. The second section consisted of a question about the size of annual investments in developing: (a) product related research and development, (b) processes and equipment, (c) staff training and education and (d) environmental programs. The fourth section was made of items about the environmental practices such as the availability of an Environmental Management System (EMS). The items in this section were all developed by the authors for the lack of constructs in the literature to measure this area.

3.2. Data Collection

While the questions addressed the marketing, finance and operations departments, the questionnaire was targeted at one individual, i.e., the production, quality or general manager. Although this may affect the depth of the questions and increase the possibility of "subjective bias due to an individual's unique prospective and limited access to information" [15], it was unavoidable as the response rate would significantly drop if multiple sources in the same company were targeted. Nevertheless, this limitation helped in assessing the state of communication between departments based on the knowledge of one manager about other departments. The survey was administered using SurveyMonkey and supported by telephone invitations whenever possible. Fellow academics were also requested to invite their contacts in industry. A total of 36 companies from 8 different sectors responded to the questionnaire.

4. Results and Discussion

4.1. Sustainable Manufacturing

Two variables were used to provide an initial assessment of the environmental performance of the participants. They were founded on two questions about the level of improvement in (i) material, water and energy consumption and (ii) waste and pollution emission, compared to 2-3 years ago (based on a 1-5 Likert-scale). The descriptive statistics show that the reduction of material, water and energy use is achieved more successfully than the reduction of waste and pollution emissions. (Mean= 3.17, σ= 0.650) and (Mean= 2.87, σ= 0.968) respectively. This can be attributed to the lack of EMS that allows for measuring the environmental performance, as the results show that only 36% of participants deployed an EMS. This is expected as manufacturers are still focused on cost reduction and operational efficiency more than environmental management [14]. To better understand the state of SM, an evaluation of the recommendations of Kashmanian et al. [3] was performed. The results show that only 16% of the participants meet the terms of SM.

4.2. Ranking the Factors

To prioritize the factors that we categorized as supporters of SM drivers, we run a Principal Component Analysis (PCA) test, a technique for identifying groups or clusters of variables [16]. This will split the variables to a number of components (groups) based on the interrelation between these variables and will also determine the importance of each component/group based on the percentage of variance they explain. The loading of variables on each of the groups/components will determine the ranking of the factors under investigation. The analysis was performed with the statistical software SPSS. The Kaiser-Meyer-Olkin (KMO) and Bartlett's tests confirm that our sample is adequate for conducting PCA as it exceeds the cut-off of 0.5 (KMO =0.601) with a significance of less than 0.05 (Sig. =0.003). PCA revealed the presence of four groups with eigenvalues exceeding 1. These groups are arranged according to the percentage of variance they explain as shown in Table 2. Table 3 shows the strong loadings of each of the variables on the different components/groups. Based on the information in Table 2, SPSS rank the variables/factors according to their component contribution and their loading on these components. The factors in Table 3 are ranked according to their importance. In the study participants were asked to rank the drivers as a single variable, which results in an incomplete understanding of SM. It is observed from the results of this study that fragmenting the SM drivers to their underlying factors provides a better picture of the factors' significance. Whereas in typical SM studies, the importance of individual factors is overlooked.

Table 2. Total Variance Explained.

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	**3.488**	**34.876**	**34.876**
2	**1.885**	**18.855**	**53.731**
3	**1.593**	**15.931**	**69.662**
4	**1.014**	**10.135**	**79.797**
5	.588	5.879	85.677
6	.447	4.470	90.147
7	.392	3.920	94.066
8	.319	3.189	97.255
9	.159	1.592	98.848
10	.115	1.152	100.000

Extraction Method: Principal Component Analysis.

4.3. Correlation Between Factors

Given the nature of the data, Spearman's test was chosen to compute the correlation between the ten factors under study and other variables to learn more about SM. The analysis produced a large table that cannot be included in this paper. A summary of the main statistically significant findings is outlined below:

Company size is positively associated with the level of implementation of Six Sigma ($r = .417$, $N = 20$, $p = .031$) and the importance of environmentally friendly activities to win orders. That indicates that larger companies tend to deploy advanced management systems and are more exposed to customers' environmental demand.

Market concentration is positively associated with the importance of a wider product range ($r = .360$, $N = 31$, $p = .047$), and Market competition is positively associated with the importance of price to win orders ($r = .370$, $N = 31$, $p = .041$). Whereas the importance of environmentally friendly products to win orders shows no significant correlation with market conditions, however, it tends to be more related to Competitive markets ($r = .329$, $N = 31$, $p = .071$).

The relation between 'emissions, waste and pollutants' and operational performance indicators such as 'quality, delivery, workers' involvement, 'the level of supply chain integration' were weak as respondents did not have a clear measure for this variable. This is evident as only one of three companies deployed an Environmental Management System. Nevertheless, operational performance correlates positively with material, water and energy consumption. This has also been reported by Yang et al. [12] who found that improvements in operational performance have a positive effect on environmental performance by means of reducing resource consumption.

The factor 'Bargaining Power of Suppliers' was positively associated with 'Spending on Environmental Improvements' (r = .460, N = 21, p = .036) and also with 'Spending on Employees Training' (r = .329, N = 31, p = .071). This confirms that supply chain integration encourages companies to develop their capabilities to achieve better performance.

Table 3. Factor ranking from the Rotated Component Matrix[a].

Factor	Component			
	1	2	3	4
The level of implementation of Six Sigma	**.875**	.222	.200	.163
The level of supply chain integration	**.847**	-.112	.203	.101
The level of implementation of lean manufacturing	**.792**	.213	-.179	.076
Market competition level	-.084	**.919**	.217	.005
Importance of environmentally-friendly products to win orders	.192	**.864**	-.193	-.026
Size of business	.434	**.632**	.413	-.004
Market Concentration	.134	.119	**.910**	.058
Spending on environmental improvements	.279	.034	-.236	**.816**
Bargaining power of customers	-.343	-.129	.431	**.648**
Bargaining power of suppliers	.368	.029	.411	**.646**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]
[a]. Rotation converged in 8 iterations.

5. Conclusion

Much attention has been paid to the SM drivers for their importance to shape the sustainable business. However, a more detailed understanding of how different factors affect the strength of these drivers is needed, which will allow manufacturers to focus on specifics (factors) rather than broad headings (drivers). In this study, data from a survey of manufacturing companies was used to analyze ten factors that underlay four drivers. The analysis produced a ranking of the ten factors, which provides a better understanding of the importance of these factors than when drivers are ranked.

The driver Competitiveness was found to be one of the strongest drivers as two of its factors rank 1st and 3rd. This indicates that a special attention should be given to Lean and Six Sigma to attain SM. Therefore this research project will carry on developing a framework to enhance Lean and Six Sigma with other environmental-impact assessment tools for use by SM. This paper may encourage future research to undertake broader studies to include all factors, as the current study was limited to only few factors that were available from the survey data.

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