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GREEN MANUFACTURING IN AUTOMOBILE INDUSTRY TO IMPROVE THE EFFICIENCY AS WELL AS ENVIRNOMENTAL CONDITIONS

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ABSTRACT

In this paper the green manufacturing is implemented in the automobile industry. The green manufacturing in very effective in the automobile industry. In this paper the green manufacturing is used by the sustainable design to improve the efficiency as well as environmental condition. With regard to the environment, the major environmental concerns in the 21st century are: atmospheric pollution (and its consequences for human health, global warming and ozone layer depletion), scarcity of freshwater, raw material and land availability. All these environmental impacts have a great impact on how companies manage their business, and therefore, they are also a driver to innovation. For instance, the availability of land can create a pressure on the prices for land disposal, which “forces” organizations to innovate in order to reduce the waste from their production sites.

KEYWORD: Green manufacturing, automobile industry, sustainable design, environmental friendly.

INTRODUCTION

With regard to the environment, the major environmental concerns in the 21st century are: atmospheric pollution (and its consequences for human health, global warming and ozone layer depletion), scarcity of freshwater, raw material and land availability. All these environmental impacts have a great impact on how companies manage their business, and therefore, they are also a driver to innovation. For instance, the availability of land can create a pressure on the prices for land disposal, which “forces” organizations to innovate in order to reduce the waste from their production sites.

Within this new context for innovation management, we would define green innovation as those innovations in the products, processes or in the business model that lead the company to higher levels of environmental sustainability. A higher level of organizational environmental sustainability is reached by the minimization of environmental impacts, and mainly by, the creation of positive impact on the environment.

Consequently, Green Innovation Management could be defined as the process to identify, implement and monitor new ideas that improve company’s environmental performance while enhancing its competitiveness. Identification includes not only the understanding of environmental demands (shortage of resources, new environmental legislations, public pressure, etc), but also customer’s requirements and acceptance of environmentally-friendly products, competitors’ actions, amongst other factors that need to be considered in the innovation of processes or products. Implementation refers to the development of the idea in the market. And finally, monitoring is the activity that should feedback the company about its green innovation in order to enhance the learning of innovating in sustainable way.
Green Innovation can happen either to respond to local or global environmental concerns or to construct an environmental leadership in the sector. Interestingly, Green Innovation can have ecological or economical motivation, and as other types of innovation, it can be incremental or radical.

In order to illustrate the management of green innovations, the automotive sector will be taken as an example. The automotive industry is one of the industries that have visibly suffered a strong demand for higher environmental performance. This industry have enjoyed years as the main source of employment and economic growth and still have a strong political influence; nevertheless, today it is being pointed out as one of the major contributors to air pollution in urban centers. Indeed, the benefits of cars are clear: they provide a door-to-door transportation system, the means to gaining access to life's necessities and employment, and a source of pleasure and social status. However, despite these benefits there are environmental burdens as well: local air pollution, greenhouse gas emissions, road congestion, noise, mortality and morbidity from accidents, and loss of open space to roads, car parks and urban sprawl (Vergragt, 2006). Thus, companies in the sector have been trying different strategies to overcome these challenges.

LITERATURE REVIEW

The automobile is one of our least sustainable systems and the main issue is overproduction. Yet, the current automotive business and manufacturing models depend on high levels of production due to the need for economies of scale determined by the chosen production technologies. These technologies center on the internal combustion engine and the all-steel body. This paper shows through a review of the 'leagile' literature, that a new understanding of the factors that determine the 'decoupling point' between lean and agile processes can be used in order to bring about a radical shift in economies of scale in car production such that lower volume production becomes feasible thereby reducing the need for overproduction and enabling a move towards more sustainable car production and hence consumption. A case study of the Morgan Motor Company is included to illustrate how such an approach could work in practice [1]. Increasing pressures and challenges to improve economic and environmental performance have caused developing countries in general and automobile manufacturing firms in particular to consider and start implementing green supply chain management. It is emerging as an important approach which not only reduces environmental issues but also brings economic benefit to manufacturers. Recently, there are intensive studies on the issues, which have been dealt with extensively by practitioners and academicians. However, studies on performance evaluations are few. In responses this study explores the criteria that influence the performance of the automobile manufacturing industry, using the fuzzy set theory and Decision Making Trial and Evaluation Laboratory. The hybrid method evaluates its performance to find key criteria in improving the manufacturers' green performance. Findings show that the increase of cost for purchasing environmentally friendly material is the most influential and significant criterion, while the pollution control initiatives is the most effective criterion. Managerial implications are also discussed and concluding remarks are made [2]. Green supply chain management (GSCM) has emerged as an important organizational strategy in modern business environment. It has been touted as an efficient approach to enhancing manufacturing sustainability. However, how to develop and stimulate green partnerships among supply chain partners remains a challenge. This study examines how institutional theory influences GSCM practices and supply chain performance by examining whether firms submit to institutional pressures in their adoption of green practices in addition to seeking economic efficiency. Two research questions are addressed: (1) Are GSCM practices motivated by institutional variables (external pressures), and (2) what are those "institutional variables" and how are they contributing to the diffusion of GSCM practices? Based on the data collected from the U.S. and Taiwan manufacturing plants in the electric and electronics industry using survey method, structural equation modeling (SEM) was performed to examine theoretical relationships among various institutional variables, green supply chain practices, and manufacturing performance. The findings prove that pressures from institutional actors have a significantly positive impact on GSCM practices adoption, which in turns improve organizational performance. This study provides managers with valuable implications and guidelines in enhancing their efficiency and performance through meeting standards from institutional pressures [3].

EXPERIMENT SETUP

CLSCM is the totality of green purchasing, green manufacturing and material management, green distribution and marketing as well as reverse logistics [10, 18, and 21]. Thus, CLSCM is a method to design and/or redesign the supply chain that incorporates recycling of metals and plastics, repair and reuse of parts and components for the production of new devices, remanufacturing and/or refurbishing of entire discarded products for use as second-hand devices [21,22]. Fleischmann *et al.* [23], and Wells and Seitz [10] believed that operations and potential flow of materials in a CLSC should combine the forward and reverse supply chains. French and LaForge [24], and Guide and van Wassenhove [25] have defined CLSC to include manufacturing and distribution of new products, and the return of the used products from the customer back to the manufacturing plant through reprocessing operation and back to the supplier. CLSCM involves the minimization of a firm's total environmental impact from start to finish of the supply chain and also from beginning to end of the product life cycle [11,26]. Rao [27] further pointed out that greening the supply chain involves manufacturers' integration of green purchasing, total quality management, employees' empowerment, customers' focus, continuous improvement, waste reduction, life cycle analysis and environmental marketing. According to Dyckhoff *et al.* [28], an environmental supply chain management should go beyond the traditional supply chain processes to include considerations on end-of-life products, thus justifying the importance of CLSCM.

BENEFITS OF CLSCM FOR THE AUTOMOTIVE INDUSTRY

End-of-life vehicles (ELVs) are returns generated at the product's end of life stage. The management of ELVs has become a very vital issue for automobile manufacturers worldwide in the last decade due to mainly the implementation of the Directive 2000/53/EC in the European Union [9,29,30]. The Directive on ELVs lays down minimum standards for the acceptance of recycling and disposal in which European automotive industries have to satisfy 85% recoverability in their ELVs by 2006 and 95% by 2015. Since closing the loop involves the implementation of an effective and efficient reverse logistics, CLSCM will be a source of competitive advantage [14,27]. In the same light, it has been stated that an increase in the cost associated with disposal of waste and acquisition of landfills has led manufacturing organizations to intensify efforts at exploring economically viable alternatives [31-33]. Therefore an efficient CLSCM is economically advantageous.

It has been observed that closing the loop is very instrumental towards achieving a complete green supply chain management (GSCM) [34]. Since one of the major reasons for GSCM is to eliminate or minimize waste in the form of energy, emission, hazardous chemical and solid waste [14,17,35], CLSCM will invariably boost the actualization of this objective. Schultmann *et al.* [9] supported that CLSCM compliments GSCM. It is an established fact that recycling utilizes less energy and produces less pollution in contrast to making things from scratch [36]. It was further stated that significant CO2 emission reductions can be achieved through an appropriate solid waste management process such as CLSCM. Furthermore, investments in waste management can lead to net emission savings of up to 20% [36]. Thus, CLSCM will enhance the reduction in green house gas effect and global warming in general. This will in turn enhance the sustainability of manufacturing processes. This is supported by the assertion that it enhances the conservation of the industrial ecosystem [26]. It was further stated that total quality management for waste elimination has significant potentials for improving environmental performance while driving improvement in productivity as well as cost reduction [35]. Closing the supply chain loop will serve as a strategy to provide the necessary information which is required in the fulfillment of the limitations and restrictions posed by environmental legislations and various regulations [9,14,27,37,38]. Some studies have observed that due to the advent of environmentally responsible manufacturing, CLSCM has become an avenue to boost organizational competitiveness and comply with environmental requirements of various regulatory bodies [9,39]. This trend has been accelerated by product-oriented legislations in the last decade, especially in the European Union [30]. Therefore, there is a need to close the loop making the supply chains a closed-loop [6,28]. Thus, closing the loop is an effective way of achieving an effective and efficient GSCM. In summary, the overall sustainability of the supply chain and the resulting products would be greatly enhanced by CLSCM.

PERFORMANCE MEASUREMENT FOR CLSC

Bhagwat and Sharma [40] described performance measurement as the feedback on operations which are geared towards customer satisfaction and strategic decisions as well as objectives. Thus, CLSC performance measurement involves quantifying the efficiency and effectiveness of all the activities and processes geared at achieving a CLSC [41]. Performance measurement reflects the need for improvement in operational areas which are found wanton in their performance measures [40]. Since, closing the supply chain loop is a continuous process which is perfected over a period of time, it becomes imperative to measure the state of its implementation from time to time to determine its performance. This is in line with the assertion by Tsoulfas and Pappis [37], that the major reasons for environmental performance measurement of a supply chain include identification and prioritization of opportunities for improvement. Performance measurement in a CLSC also helps decision makers to benchmark and compare alternative scenarios which might lead to the development of better products and processes including reverse logistics [11,37]. This assessment also serves as a provision of knowledge of an organization's products, which leads to a robust basis for price calculations and provides an avenue for a closer communication with customers, other interest groups and the society at large, thus significantly contributing to the maintenance or creation of a positive corporate image [37]. Finally, performance measurement for a CLSC also ensures that information is made available which can aid in the fulfillment of limitations and obligations posed by regulations and certain environmental legislations. On the other hand, it will induce the overall achievement of sustainability in an organization's supply chain.

THE PREVIOUS RELATED STUDIES ON GSCM AND ITS CRITICAL PERFORMANCE AREAS

Under this section, previous studies which have looked at key success areas from a general point of view of green and/or sustainable supply chain either directly or indirectly are considered. Since GSCM is associated with a CLSC [7,10,42], insights and related measures can be elicited from GSCM measures. From the literature, it was found that most of the previous studies in CLSC are mainly on network design, planning and optimization as evident in some studies such as Kannan *et al*. [43], Schultmann *et al.* [9], Yang *et al*. [44], Amaro and Barbosa-Póvoa [45], Hammond and Beullens [46], Vlachos *et al.* [47], Amaro and Barbosa-Póvoa [48], Flapper [49], Salema *et al*. [50], and Guide *et al*.[51]. Others looked at strategic alliance, implications and benefits relating to a CLSC [18,39,52,53]. Studies which dealt with performance measures, areas and metrics are not available. Also considered are the traditional supply chain measures which are measures used in the assessment of the performance of a normal supply chain in the absence of environmental consideration. Following this review, inferences shall be drawn upon to propose a comprehensive set of key success indicators for CLSCM in the automotive industry.

According to Shepherd and Gunter [54], there have been numerous studies that have focused on performance measurement in supply chain management. They study went ahead to reveal that more than 40 studies have focused on performance measurement systems and metrics for supply chains. Most of these studies dealt with traditional supply chain performance measurement which involved the normal supply chain without consideration on the environment. The following measures have been identified as the major measures: cost [55-58], time [55,56,58-60], quality [55,56,58-65], flexibility [55-59] and finally, innovativeness [58]. Based on the inclusiveness of these measures, cost, time (responsiveness), quality, flexibility and innovativeness, they were considered the most important in normal supply chain performance measurement.

With the advent of environmental concerns attributed to manufacturing operations, the metrics and measures for supply chain management have been expanded. According to the study by Seuring and Muller [7], the research in the field of environmental supply chain is still dominated by green/environmental issues, without any formal integration of all the dimensions of sustainability such as environmental, social and economic. Thus, the study highlighted the scarcity of papers which took these three into consideration. The analysis of performance measurement systems could be based on three categorical stages which include the individual metrics, a set of measures which forms the performance measurement system, and finally, the relationship between the measurement system and the environment in which it exists [41]. Therefore, there is thus a need to review existing literature which has looked at green supply chain measures and metrics directly or indirectly. The areas which have been considered in the literature will be termed as generic. This is because they are considered from the broad green supply chain perspective. Vonderembse *et al.* [66] stated that each product has its uniqueness and thus, has different supply chain dynamics. The same goes for the automobile chain. It is on that note that this study tries to synthesize these generic measures and combine the economic, social and green performance areas for the automobile supply chain.

The first study considered here is Zhu *et al*. [67]. They looked at the construct and scale of evaluation for green supply chain management implementation amongst manufacturers. The areas which they identified in their study included compliance from senior and mid managers, availability of environmental auditing systems, cost of compliance, eco-labeling of products, availability of second tier environmental evaluation, level of customer cooperation in the environmental scheme, recyclability of materials, percentage of emission from materials, level of waste generation, greenness of packaging adopted, level of energy consumption, level of suppler certification in the ISO 14000 regulation, waste water management, and finally availability of recycling process. Another study that looked at these success areas is van Hoek [17]. In general the areas identified were: consideration on raw materials suppliers, level of green materials, level of re-use of materials, application of design for dis-assembly, type of transportation, the nature of packaging, emission rates and energy, efficiency per material, percentage of virgin materials, volume of goods disassembled per hour, degree of utilization of materials, transport equipment, amount of air in package, percentage by volume of recyclables and finally recycling operation. Beamon [11] investigated the environmental factors which were crucial for the development of an extended environmental supply chain, otherwise known as a green supply chain and also presented performance areas which were necessary for an effective management of an extended supply chain. She went ahead to propose a general classification which was based on product and process life cycle and came up with categories which included resource use, product recovery, re-manufacturability, re-use, recycling, product characteristics, waste emission and hazard exposure, economic, and finally emission.

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Tsoulfas and Pappis [37] proposed a decision model based on environmental performance indicators which could help in sustainable supply chain considerations and decisions. Their classification of areas was based on principles which were in line with activities within a production system. These activities included product design, process design and production, cost associated with the process, packaging, transportation and collection, recycling and disposal, greening the internal and external business environment, and various miscellaneous management issues. Hervani *et al.* [14] came up with an integrative framework for the study, analysis and evaluation of supply chain management performance tools using case studies, experiences and literature related to performance measurement in environmental supply chain management. The areas identified by Hervani *et al.* [14] were based on the ISO 14000 accreditation guidelines. Another guideline upon which their study was based was the United States Environmental Agency's TRI and Global Reporting Initiative.

Other studies include that of Rao [27], who used a survey questionnaire to elucidate measures from practitioners in the area of green supply chain. Measures identified were level of optimization of processes to reduce noise, level of cleanliness of the processes that are energy saving, waste saving, and water saving, level of compliance to environmental issues, level of substitution of environmental questionable materials, recyclability of materials internal and external to the company, level of optimization of processes to reduce water usage, percentage of optimized processes aimed at the reduction of solid waste, percentage of recyclable materials used, percentage of questionable materials in the chain, consumer enlightenment on environmental issues, adoption of more environmentally friendly transport systems, eco labeling, recovering of the company's end of life products, recoverability of packaging, level of usage of waste from other companies, level to which air emission is reduced and returnability of packaging. Rao and Holt [68] conducted a study which looked at potential linkages between green supply chain management, as an initiative for environmental enhancement, economic performance and competitiveness amongst a sample of companies in South East Asia. The important areas which were highlighted included: level of environmental-friendly waste management, environmental improvement of packaging, taking back of packaging, eco-labelling, recovery of the company's end-of-life products, level of information provision for consumers on environmental friendly products and/or production methods, level of application of environmentally-friendly transportation and the extent to which environmental total quality management principles such as worker empowerment are incorporated into the chain. In the outbound process, the followings were identified to be suitable for the measurement of a sustainable supply chain: percentage of environmentally-friendly raw materials, percentage of substituted environmentally questionable materials, taking environmental criteria into consideration, level of environmental design considerations, level of solid waste and emission, use of cleaner technology processes to make savings in energy, water and waste and internal recycling of materials within the production phase.

McIntyre *et al.* [16] developed environmental performance areas, which provided performance measures for the entire supply chain, for each functional element within the chain and for different product delivery scenarios using Xerox Corporation as the case study company. They applied an environmental common denominator approach in which all processes and operations were built around environmental themes. These included, the amount of energy consumed, materials intensity and pollutants emission *etc.* In Table 1, a summarized version of the review on related studies is presented.

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Table 1. Previous Studies and Identified Areas.

Authors / Generic Measures	Beamon [11]	Tsoulfas & Pappis [37]	Hervani *et al.* [14]	Zhu *et al.* [67]	Van Hoek [17]	Rao [27]	Rao & Holt [68]	McIntyre *et al.* [16]
Sustainability cost	√	√	√	√	x	x	x	x
Customer commitment	x	x	x	√	x	x	x	x
Product features	√	√	√	√	√	√	√	√
Process optimization for waste reduction	√	√	√	x	√	√	√	√
Management initiatives	√	√	√	√	√	√	√	x
Environmental social concerns	x	√	√	x	x	x	√	x
Supplier initiatives	x	x	x	√	√	√	√	x
Recycling	√	√	√	√	√	√	√	√

THE AUTOMOBILE SUPPLY CHAIN

According to world statistics, the automobile industry is the world's largest single manufacturing sector [69]. The sector is believed to be an engine of industrial development, provider of technological capability, and generator of inter-industry linkages. The constant growth in the world's population has further heightened the demand for vehicles. This in turn has led to an increase in car production plants around the world. There is a high consumption of material resources attributed to this manufacturing operation, especially in the area of metals and plastics. This consumption is characterized by environmental issues such as emission and waste management [4,9]. In a typical automobile manufacturer, there exist between 200 and 300 suppliers. These suppliers are responsible for manufacturing and provision of various components of the vehicles. Thus, the implementation of CLSCM is one important strategy that will guarantee the automotive industry's environmental, economical and social sustainability [39,70]. This will in turn enhance the CLSC practices in this industry.

RESULT

A two-in-one chain measurement approach, which separates the CLSC into two different chains for the automotive industry, has been proposed. These are the forward and reverse supply chains. The reverse chain can also be described as a reverse logistics. A set of key performance measures has also been developed based on the model. The rationale behind this model is that measuring the entire chain as once makes the objective of the process cumbersome and imprecise. This is because the two chains complement each other, but have different primary objectives. First, the forward chain makes sure that the customers' needs are fulfilled efficiently by getting the products to them at the right time, and in the right quantity under suitable conditions [13,73]. At the same time, this chain makes sure that the products consist of materials that make recycling of the ELVs a possibility and success to an acceptable standard [11,77].

On the other hand, the backward chain is mainly concerned with waste reduction. The European Union expects that by the end of 2015, the waste disposable at the end of the process should be less than 5% of the 90% of the ELVs [9,28,29,71]. Therefore, this chain is mainly concerned with efficient collection, recycling and integration of the recyclates back into the manufacturing stream in order to achieve a considerable low-level waste at the end of the recycling process. This will in turn reduce the mass of the end-of-life vehicles, which end up in landfills across the society, while minimizing the emission from the recycling process. It is also believed that this model will enhance the performance measurement for a closed-loop supply chain, as the objective of the measurement will be clearer and more precise.

Secondly, measurement results can easily be interpreted based on the objectives of the performance measurement, thus easier to figure out areas which are found wanton based on the results. Another important point is that, the data to be collected for the performance evaluation will be clearer defined as each set of data/measures will be aimed at a

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specific objective in the performance measurement, in contrast to a multiple range in the case of combined performance measurement of the entire supply chain (from suppliers back to suppliers).
The use of the model will be in CLSC performance measurement. Thus, data collection can be carried out in line with the model and the performance areas. It will on the other hand enhance the ease of assessment of the automotive supply chain. It can also be applied in the establishment of any green supply chain performance measurement system for this industry. In the same light, this model and performance areas will serve as guide in performance measurement of other products, including the short and lengthy life cycle-products. It is believed that this will enhance overall ease of measurement.

It is also worth noting that integrating both the key green performance areas and the normal supply chain performance areas will enhance sustainability by fostering environmental concerns and social concerns while maintaining an economically viable supply chain. These will in turn help fulfill numerous environmental regulations, present a reputable corporate image and improve the financial returns. This should satisfy all the stakeholders in the organization at large and boost the overall environmental collaboration [77]. The sustainability of the supply chain and the industry will be greatly enhanced by applying this model and the proposed performance areas in the management of any organization's CLSC.

A suitable approach for the performance assessment of the automobile CLSC has been proposed in this study through a careful review and analysis of the automotive industry and CLSC. The study began with the establishment of the basis for performance measurement of a green supply chain with respect to the automotive industry using a new approach. In conclusion, 14 and 13 key performance areas have been proposed for the forward and reverse chains, respectively, for the performance measurement of a CLSC based on the proposed model. Based on the reasons discussed earlier, it is believed that this approach will provide an efficient and effective supply chain performance measurement for the automotive industry. It is recommended that this approach be used against the traditional supply chain method and comparison could be made and inferences drawn to investigate the efficacy of the approach. We also recommend that the approach be extended to other products, both the ones with long and short useful life to see how applicable and efficient it can be. Finally, it is recommended that suitable metrics should be developed for the assessment of CLSC performance using these key performance areas in line with the established approach.

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