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Analyzing the drivers of green manufacturing with fuzzy approach☆

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ABSTRACT

Green issues have gained more importance in contemporary globalization. Recent years have seen manufacturing processes understand the green issues due to the social and environmental concerns involved. The drivers of green manufacturing, however, have not been thoroughly investigated. Thus, this paper investigates the responsibility of identifying twelve common drivers of green manufacturing from the combined assistance of existing literature, industrial managers, and expert opinion in the relevant field. A questionnaire on these common drivers was circulated among 120 leading firms in south India, and aided by their replies; a pair-wise comparison was made among the drivers. The pair-wise comparison is used as an input data and the drivers were analyzed on its basis. The analysis resorted to the use of a fuzzy Multi Criteria Decision Making (MCDM) approach. The obtained results are validated by a two-stage sensitivity analysis, namely: (1) using different de-fuzzification methods that are further evaluated through the Spearman coefficient and (2) assigning varying weight to the essential top priority drivers of green manufacturing among all common drivers. This study helps firms to stimulate an essential driver for quick and better adoption of green manufacturing. Finally, the paper concludes with some insight into the future path of green manufacturing in developing countries and an acknowledgment of the study's own limitations.

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1. Introduction

Due to scare resources and increasing population, the conservation of environmental quality has become essential. In many aspects, environmental problems have affected regional and global cooperation and have even prompted conflicts (Chen, 2005). Hence, the practice of green activities has become mandatory to balance these conflicts; even manufacturing processes cannot make an exception. While green concerns have been endorsed by some individuals for decades, the 1987 report of the World Commission on Environment and Development (WECD) revealed that current environmental patterns have altered the planet and its living organisms, including human beings (Sarkis and Rasheed, 1995). In this connection, many green strategies were evolved and integrated in our real life operations and management. Likewise, the integration of green activities in manufacturing has emerged as an important research topic in recent years. While existing research generally defines green manufacturing from their own perspectives through their experiments and experiences, the most referred explanation is provided by Melnyk and Smith (1996), who define green manufacturing (GM) as "a system that integrates product and process design issues with issues of manufacturing planning and control in such a manner to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing environmental impact while trying to maximize resource efficiency". More simply, green manufacturing includes environmental consciousness in manufacturing. Generally, the three "R"s (remanufacture, reduce, and reuse/recycle) are one main strategy of green manufacturing, which includes activities such as reducing hazardous waste volume, minimizing coolant consumption while machining, and calculating proper energy mixes to ensure a sustainable energy source (Dornfeld et al., 2013). To report cleaner production, industries must undertake environmentally conscious policies for operations such as product development, manufacturing, service and distribution, and end-of-life activities in addition to the growing awareness of sustainable issues (Subramoniam et al., 2009). GM helps a firm financially by reducing

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waste, sustaining utilization of materials, and minimizing pollution which harms the environment. Existing environmentally concerned literature exposed environmental gains for businesses (Mudgal et al., 2010; Sarkis et al., 2011; Perron, 2005; Shipeng and Linna, 2011; Kannan et al., 2008; Carter and Rogers, 2008).The importance of green manufacturing serves as the basis for this paper with the study being conducted in industries that focus on South India. The strict policies and regulations in developed nations (like U.S and EU) result in effective GM system implementation in those countries. But in developing scenarios, GM is still in initial stages; recent studies on GM in India by Rehman and Shrivastava (2013a,b) revealed that the majority of the population don't have enough awareness on GM in India. In addition to this, India is one of the largest populated nations, ranking in 4th position on CO_2 emissions in 2013 (Trends in Global CO_2 Emissions, 2013). Effective GM implementation creates job opportunities by balancing the economic crisis with practicing the efficient use of resources, which are obvious needs for a developing nation like India. When we compare the Indian scenario with other developing contexts, it is evident that the other contexts are entirely different and unrelated to one another, because economic capacity ultimately decides whether GM will be effectively implemented. It is a known factor that every developing nation's green investments are different from one another which makes the nations heterogeneous in GM implementation. Also, poor environmental concerns in developing nations impact the whole global chain. Hence, there is a fundamental urge to analyze green manufacturing in an Indian context which also acts as a pioneering approach for all developing nations. In this regard, to reveal the importance of the GM, to encourage awareness, and to address the existing research gap, this study assumes the responsibility to analyze the drivers of GM in an Indian scenario. Generally, GM is initiated by the pressures of some factors – external, internal, societal, committal – called drivers. These drivers help to adapt green manufacturing to industries either voluntarily or mandatorily. This paper aims to collect these common drivers of green manufacturing from various sources and to analyze them with the help of Analytic hierarchy process (AHP) in fuzzy environments which will reduce the vagueness of the results. We seek to provide the priority and to identify the essential driver among common drivers which were framed through references. Analytic Hierarchy Process (AHP) is a MCDM tool which helps to solve complex problems by separating them into simple problems by implementing a level of hierarchies; each level represents a set of criteria or attributes connected to those simple sub problems (Sambasivan and Fei, 2008; Saaty, 1980, 1990). Due to this flexibility, AHP has been chosen as the solution methodology for this problem. In this paper, Section 2 defines the literature review that plays a major role in data collection. The problem description is placed in Section3. Section 4 provides the methodology of the study, and Sections 5 and 6 point out the application of the proposed model, and our results with respective discussions. Section 7 concludes the paper.

2. Literature review

The literature review is organized into four different sub sections. The first provides an overview and details of current attempts made by researchers in the field of green manufacturing. We further extend the discussion with our pinpoint focus on an Indian scenario in the second sub section. The third sub section explores the drivers of green manufacturing in existing literature. Finally, the fourth sub section reveals the gaps in the existing attempts and presents the highlights of this research. These sub categories ensure an improved understanding of the theory behind the title.

2.1. Green manufacturing

The intervention of external auditing certification by British standard 7750 in the early 1990's resulted in the integration of corporate environmental policies with programs such as GM (Green Manufacturing) or EMS (Environment Management System) getting more attention over the last decade (Morrow and Rondinelli, 2002). The International Standards Organization (ISO) published the first EMS standard internationally in 1996 known as ISO 14001 (Agan et al., 2013). Due to the rapid development of green manufacturing, many researchers focused their attention on this theme and conducted various studies with extensions. Richards (1994) studied the life cycle approach and design guidance with the EMS along with its barriers and challenges for effective implementation. Handfield et al. (1997) explored green practices in the furniture manufacturing industry through interviews conducted with five environmental managers. Vachon (2007) revealed that green supply chain practices have a higher impact on suppliers than on customers in his discussion of the green supply chain practices from both perspectives (suppliers and customers). Pun et al. (2002) identified success factors in EMS adoption and implementation and also investigated the relationship between environmental strategies and environmental management. They also provided best practices through their examination of several successful cases. Matthews (2003) recommended new changes in internal benchmarking of the EMS system through suggested changes in the benchmarking cycles of plan, do, check, and act. Azzone and Noci (1998) defined green manufacturing strategies and ways to implement them with regard to operations management; they also identified the most effective performance measuring system for deployment of green manufacturing strategies. Despeisse et al. (2013) worked in the research fields of sustainable manufacturing and provided an approach to systemize identification opportunities in factories. They also introduced the tactics for resource efficiency manufacturing. Chin et al. (1999) provided an overview of strategic issues and attributes involved in implementing EMS by adopting the ISO 14001 and by evaluating success factors using AHP to implement ISO 14001–based EMS. Searcy et al. (2012) found the colloquium on ISO 14001 and revealed the challenges in implementing the ISO 14001 in environment management systems. Sangwan (2006) presented the multi attribute decision model to justify green manufacturing by performance value analysis attributes identified from strategic, tactical, and operational issues. Gutowski et al. (2005) observed the status of environmentally benign manufacturing from three main nations including Japan, Europe, and the United States; this committee evaluated research questions and provided solution methodologies to relevant research questions. Hui et al. (2001) carried out a survey in Hong Kong to analyze the current status of the nation by investigating the critical factors considered for implementing GM/GMS. In addition, a monthly review explored the status of green manufacturing around their region. For instance, *Business Horizons* and the *Harvard Business Review* published some pieces on environmental management issues explaining the importance of EMS (Handfield et al., 1997). In *Business Horizons*, Sarkis and Rasheed (1995) published a seminal paper concerned with greening manufacturing functions. It explored all the needs, motivations, and obstacles of green manufacturing practices. Lun (2011) discussed the impact of GM practices on organizational performance with a perspective on the GM elements using relevant models and indicators. Li et al. (2010) evaluated six major objectives (quality, time, service, cost, environmental impact, and resource consumption) after the implementation of green manufacturing with the assistance of proposed methodology. Vijayaraghavan and Helu (2013) discussed the various technologies which assured

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