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Integration of green lean approach with six sigma: an application for flue gas emissions

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ABSTRACT

Environmental considerations have led organizations to take an important role in designing environmentally-friendly, recyclable products to complement improvements in the environmental standards of services. In this context, the application of lean practices may result in pollution reduction. In this paper, firstly, the integration of green lean approach is discussed, and then the limitations of green lean approach are identified. Finally, we integrate the Six Sigma approach in order to overcome these limitations, and assess the performance of the green lean approach. Measurement System Analysis and Gage Control are used as methodology to measure the variations of the process in order to decrease unfavorable ecological impacts of companies' products or services, while enhancing environmental efficiency.

1. Introduction

In order to be competitive in the global market, ensuring products/services with highest quality and lowest cost has great importance. In various fields, many ideas and approaches were generated during the last years of World War II. Correspondingly, in recent years, the lean manufacturing approach has attracted much interest from many different fields (Lewis, 2000).

Lean practices can be defined as a set of techniques that intend to remove various types of waste throughout the value chain. Techniques can be grouped together as clusters such as total quality management (TQM), just in time (JIT), and total preventive maintenance (TPM) (Furlan et al., 2011), all of which put into practice the lean philosophy of removal of waste and continuous improvement. Lean philosophy can also be applied to the supply chain by way of cooperation with stakeholders, aiming to improve the efficiency of the whole production process (Galeazzo et al., 2014).

As Womack et al. (1991) stated, lean production originates from the Toyota Production System (TPS). The research in the automotive industry, as applied by Toyota, highlighted seven significant types of waste to be eliminated in production processes. With reference to Ohno (1988), who was labeled as the father of TPS, the seven wastes are identified as overproduction, excessive inventory, transportation, unnecessary motion, defects, waiting and delay, and overprocessing. In addition, Womack and Jones (2003) introduced an 8th waste, underutilized human talent.

The application of lean practices has the potential to reduce pollution, remove the obstacles to the application of pollution reduction measurement, and emphasize the value of pollution reduction. Therefore, lean may complement green. Also, the adoption of lean production may decrease the marginal cost of reducing pollution, either by reducing the cost of applying environmental development, or bringing greater awareness of the value of pollution reduction. Hence, environmental management systems (EMS) show the similar characteristic features to lean philosophy. Like lean philosophy, EMSs deal with the removal of wastes and the application of continuous improvement (King and Lenox, 2001).

Environmental considerations lead organizations to take an important role in designing environmentally-friendly, recyclable products, in addition to providing cleaner services. Therefore, the green philosophy has emerged as an operational approach for companies to decrease the unfavorable ecological impacts of products or services, while enhancing environmental efficiency. Likewise, lean is an operational approach aiming the reduction of waste in every area of organizational activity; therefore, it seems natural to integrate lean and green (Garza-Reyes, 2015a).

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The studies within the operations management area were in agreement over the complementarity of lean and green concepts under the following principles (Jurado and Fuentes, 2014):

1) Waste Reduction Principle: The basic principle of lean production is to improve added value by decreasing and/or removing the non-value-added activities throughout the value chain. Similarly, reducing and/or removing waste is a fundamental issue for environmental sustainability by way of reducing and preventing environmental pollution (Florida, 1996; King and Lenox, 2001).
2) Process-Centered Focus: One of the fundamentals of lean production is managing quality over the whole production process. The lean focus is emphasized not only in order to solve a particular problem, but also to prevent its reoccurrence. The same is valid for the green approach, which underlines the preventive action, rather than focusing on the end of the process (King and Lenox, 2001; Sawhney et al., 2007).
3) High Levels of Participation: Another important lean production principle is the participation of people in management, which is also valid for environmental focus. Human resource management activities allow organizations to create a culture of continuous improvement, which enables environmental management principles to be applied (Rothenberg et al., 2001; Soltero and Waldrip, 2002).

Moreover, Dües et al. (2013) examined two philosophies of lean and green to produce a detailed account of the differences and similarities. “Waste and waste reduction techniques”, “people and organization”, “lead time reduction”, “supply chain relationship”, “Key Performance Indicator (KPI): service level”, and “tools and practices” were found to be common attributes. They described a lean environment as being a catalyst for the application of green approaches. In addition, it has been proposed that the integration of lean and green will lead to better performances and results for companies (Ng et al., 2015). Specifically, Bergmiller and McCright (2009) provided empirical evidence that companies which integrate lean and green philosophies have yielded greater benefits than those focusing solely on lean production.

The remainder of the paper is structured as follows. First, in Section 2, the limitations of green lean approach are examined. Then, in Section 3, six sigma methodology, measurement system analysis and gage control methodologies are presented. Section 4 describes the application. The data preparations and findings of the analysis are outlined in Section 5. Section 6 is the conclusion and discussion of future research directions.

2. The limitations of green lean approach

Although the integration of lean and green seems natural and logical, there is uncertainty over whether integration alone is sufficient to achieve simultaneous operational competitiveness and environmentally sustainable results (Garza-Reyes, 2015b).

Generally, the studies in the literature determined the relationships between lean and green concepts through underlining the similarities and differences between the two paradigms, investigating the possible benefits of their combination in different industries, and identifying their impacts on organizations and supply chains' performances (Garza-Reyes, 2015b). However, the integrated green lean approach may be subject to potential limitations, according to Garza-Reyes (2015b), who proposed integration with Six Sigma to overcome those limitations.

The integrated green lean approach is subject to the same limitations as the two approaches practiced separately. In the case of lean, Salah et al. (2010) described it is a toolbox comprised of tools to identify the potential for waste reduction. From this viewpoint, one of the main limitations is that it fails to scrutinize and target the reduction of variations in processes (Devane, 2004; Lee et al., 2013). The green approach is also subject to such variations in areas such as storage space, energy consumption, and inventory waste. Montgomery (2001) and Snee and Hoerl (2003) claimed that variation reduction is necessary to improve operations; presumably, this claim is also valid for the green approach. Moreover, the examination of variation is important because it declares, notifies, and assists the decision-making process (Devane, 2004), allowing the improvement of the performance of green operations. Another limitation of lean is a lack of lean tools related to the use of quality and mathematical tools. Statistical data to monitor the process and determine the related remaining problems may not be collected until waste has been removed (Devane, 2004; Lee et al., 2013). Because of this, Assarlind et al. (2012) proposed that lean organizations fail to make effective use of data in the decision-making process, and therefore, that organizations should employ methodologies to encourage a more scientific approach. Within this context, the lack of a data-driven approach to improve the process results in a less precise lean process (Hilton and Sohal, 2012). Lean is an operational approach focused on satisfying customers' needs and wants (Chauhan and Singh, 2012); however, it does not offer a systematic and structured approach either to monitoring processes, or solving the related problems. This systematic drawback may undermine confidence in lean's ability to scrutinize the root causes (Husby and Swartwood, 2009). Hence, the operational and green problems may not be removed from their root cause (Garza-Reyes, 2015b).

On the other hand, in the case of green, Chan et al. (2010) claimed that the implementation of decision support systems and expert systems tools has only limited effectiveness in solving problems. Unlike lean, green philosophy cannot be identified simply as a toolbox; rather, it is a concept composed of series of practices and methods (Garza-Reyes, 2015b). Because of this, the integrated green lean approach will be subject not only to the limitations of lean, but also the limitations of green. From the perspective of environmental management systems and green approach, it is possible to indicate that the limitations of green are related to strategic aspects, such as the difficulties of making strategic decisions related to investment priorities, or how to apply green initiatives in ways which also satisfy the corporate goals of profitability (Nunes and Bennett, 2010).

Since the limitations of both lean and green are inherited by the integrated green lean approach, it is important to integrate additional tools that are able to contribute to the reduction and removal of these limitations. Six Sigma is associated with such tools (Garza-Reyes, 2015b). Within this context, Six Sigma tool allows us 1) to assess the performance of the green lean process, and 2) to overcome the limitations of green lean process. Therefore, in this paper, Six Sigma methodology is applied in order to eliminate the limitations and assess the performance of the green lean process. As such, in Taguchi's loss function, environmental pollution is, in fact, a loss for a society (Gremyr et al., 2014), and therefore, there must be zero tolerance for the measurement errors or variations in environmental pollution, due to the consequences for human health. A Six Sigma tool, Measurement System Analysis and Gage Control methodology, is integrated with the green lean approach in order to identify the variability of measurement process, by analyzing resource use across the entire process. The major contribution of this paper is the emphasis of the need for the application of Six Sigma methodology to the green lean approach, and the proposal of Measurement System Analysis and Gage Control technique to satisfy the need for measurement.