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Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers

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ABSTRACT

The main objective of this research is to investigate whether or not Lean Production tools can help reduce the environmental impacts of manufacturing companies. The research is based on empirical observation inside five European companies that manufacture motorcycle components and which are also committed to Lean and environmental management. The environmental impacts of the production processes of the five companies were observed and measured before and after the implementation of five Lean tools: Value Stream Mapping (VSM), 5S, cellular manufacturing, Single Minute Exchange of Die (SMED) and Total Productive Maintenance (TPM). Comparison of the before and after quantitative results reveals interesting and novel results which contribute to the research on the effects of Lean Production on environmental impacts. In particular, VSM can be used to identify the environmental impacts of production processes. 5S can be useful for reducing oil leakage and improving waste management. Cellular manufacturing can lead to a decrease in electricity consumption, whereas TPM can help to reduce several impacts of the machines, such as oil leakage and emissions of dusts and chemical fumes into the atmosphere. By contrast, no significant improvement in environmental impacts was measured after implementation of SMED. The result of this empirical research also revealed other interesting positive effects concerning electricity consumption in general as well as standardization of activities and worker behavior. The originality of this research lies in observing and measuring the effects on environmental impacts of the implementation of five Lean tools, inviting further research toward a general model of Lean Production for the greening of production processes.

1. Introduction

For the past few decades Lean Production has been considered a well-consolidated strategy for cutting down costs, especially costs related to production processes. Lean Production stems from the so-called Toyota Production System (TPS); a term coined by Womack et al. (1991). Researching inside the automotive sector and comparing results with the performance of the excellent car manufacturer Toyota, Womack et al. reported on seven particular wastes to be avoided in production processes. According to Ohno (1988), former Executive Vice President at Toyota who can be considered the founder of TPS, these seven wastes are:

- Overproduction
- Excessive inventory
- Transportation
- Unnecessary motion
- Defects
- Waiting and delay
- Overprocessing.

By avoiding the seven wastes a company can reduce its production costs and accelerate product lead-time inside a plant layout (Chiarini, 2012a; Chiarini, 2013d).

Lean Production offers several tools to help companies reduce wastes. It is out of the scope of this paper to investigate in what ways these tools affect the wastes. The most important Lean Production tools are Value Stream Mapping (VSM) for identifying the wastes in plant layout (Rother and Shook, 2003), 5S for setting in order and cleaning up workplaces (Brunet and New, 2003), cellular manufacturing for grouping machines and workplaces (Ohno, 1988), Single Minute Exchange of Die (SMED) for reducing machine set-ups (Shingo, 1989) and Total Productive Maintenance

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(TPM) for reducing failures of the machines and equipment (Monden, 1998).

Some authors (see Section 2) claim that Lean Production seems also to have effects on the reduction of environmental impacts such as emissions into the air, water and soil, as well as efficiency of water and energy consumption. In fact, every time a Lean tool or principle is applied, there are also benefits concerning environmental management. However, it is not clear exactly what kind of relationship exists between a specific Lean tool and the environmental impacts and whether or not this relationship can be measured.

In this research, case studies based on empirical observation within five manufacturers of motorcycle components were conducted to illuminate the debate on using Lean tools as a vehicle for reducing environmental impacts within particular production processes. The observed companies have been managing Lean Production and an environmental management system according to the ISO 14001 standard (ISO, 2004) for about five years, starting from 2008. In each company the effect of specific Lean tools (i.e. VSM, 5S, SMED, cellular manufacturing and TPM) on environmental impacts has been measured in order to confirm the findings that Lean tools reduce impacts on the environment.

The next section will review the literature to assess the current knowledge on Lean and environmental management or green management. The five case studies are described in Section 3 as well as the methodology and the theoretical findings derived from the literature review. The quantitative results will be presented and discussed in Section 4. Conclusions are drawn in Section 5 as well as the practical implications and limitations of this research with an agenda for further research.

2. Literature review

There are many papers dedicated to Lean Production (Ohno, 1988; Shah and Ward, 2007) and its tools and a review would be beyond the scope of this research. The papers mainly investigate how Lean can reduce the lead time of processes to avoid the above-mentioned seven wastes.

Many authors have suggested the investigation of new strategies and tools to increase environmental performance. According to these authors, strategies such as ISO 14001 certification, Life-Cycle Assessment (LCA), waste management, reuse and reproduction, to mention but a few, should be integrated and supported by other manufacturing management systems (Zeng et al., 2010; Lucas, 2010; Jiang et al., 2011; Illge and Preuss, 2012; Spetic et al., 2012; Enderle et al., 2012; Guziana and Dobers, 2012; Fujii et al., 2013; Guoyou et al., 2013; Cheah et al., 2013; Van Hoof and Lyon, 2013; Chiarini, 2013c; Bracci and Maran, 2013). However, these authors did not directly suggest the implementation of Lean Production or of its tools and principles.

By contrast, there are few papers which directly explore the relationship between Lean Production and environmental or green management. In the 1990s some authors (Romn, 1994; NEPI, 1999; Vickers, 2000) started investigating the subject. For the first time, through observational case studies, these authors noticed a relationship between the two systems. However, in these first papers the relationship was not explored.

However, at the beginning of 2000s a more relevant debate on the topic started. Indeed, research about the integration of Lean agile systems and environmental sustainability of the supply chain seems to have become more prolific as many papers demonstrate (King and Lenox, 2001; EPA, 2003; Larson and Greenwood, 2004; Hansen et al., 2004; Kleindorfer et al., 2005; Welford and Frost, 2006; Kainuma and Tawara, 2006; Venkat and Wakeland, 2006; Bergmiller and McCright, 2009a; Carvalho and Cruz-Machado, 2009; Mollenkopf et al., 2010; Thun and Müller, 2010; Heras-Saizarbitoria et al., 2011; Seuring, 2011; Hajmohammad et al., 2013; Chiarini, 2013a; Dües et al., 2013; Shukla et al., 2013). For the scope of this research only the most significant papers in terms of integration and mutual benefits have been taken into account.

King and Lenox (2001) demonstrated that Lean Production can reduce the costs of pollution and in particular it is complementary to waste and pollution reduction. Their paper is based on a quantitative inquiry carried out within a sample of US companies from 1991 to 1996. The results validated hypotheses which correlated the Lean Production efforts of a company to its environmental management practices. However, the research did not investigate in what way and through which Lean tools a company can improve its environmental performance. Indeed, the authors invited others to investigate this direction.

In an on-line published document the US Environmental Protection Agency (EPA) presented their findings from research carried out in four American companies by means of observations (EPA, 2003). The research underlined how Lean Production can be taken into account to improve environmental performance. The research can still be considered the most exhaustive on the subject. The most important results of this research are (EPA, 2003, p. 5),

> *Lean produces an operational and cultural environment that is highly conducive to waste minimization and pollution prevention.*
>
> *Lean can be leveraged to produce more environmental improvement, filling key 'blind spots' that can arise during Lean implementation.*
>
> *Lean experiences regulatory 'friction' around environmentally sensitive processes.*

In the paper, the EPA also discussed an interesting table in which they create a correlation between the seven Lean wastes and the environmental impacts they can create. An extract from this table is shown in Table 1.

Table 1
Environmental impacts linked with manufacturing waste (source: EPA, 2003).

Waste type	Environmental impact
Defects	Raw materials consumed in making defective products
	Defective components require recycling or disposal
	More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Waiting	Potential material spoilage or component damage causing waste
	Wasted energy from heating, cooling, and lighting during production downtime
Overproduction	More raw materials consumed in making the unneeded products
	Extra products may spoil or become obsolete requiring disposal
Movement and transportation	More energy use for transport
	Emissions from transport
	More space required for work-in-process (WIP) movement, increasing lighting, heating, and cooling demand and energy consumption
	More packaging required to protect components during movement
Inventory	More packaging to store WIP
	Waste from deterioration or damage to stored WIP
	More materials needed to replace damaged WIP
	More energy used to heat, cool, and light inventory space
Complexity and overprocessing	More parts and raw materials consumed per unit of production
	Unnecessary processing increases wastes, energy use, and emissions
Unused creativity	Fewer suggestions of pollution and waste minimization opportunities