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RESEARCH ARTICLE

LEAN AND CARBON FOOTPRINT ASSOCIATION: AN EMPIRICAL ANALYSIS

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ABSTRACT

Lean has become a buzz topic in today's arena of competition. Looking at the increasing ability of lean to provide answers to the problem of global warming, this study was planned with the aim to comparatively assess the environmental performance among lean and non-lean initiated apparel units of National Capital Region (India) in terms of environment performance indicator 'Carbon footprint'. Apparel units were selected using inclusion or exclusion criteria from the member list of Apparel Export Promotion Council, Gurgaon, India. Carbon footprint emission sources were identified and calculations were done as per the standards of ISO- 14064-1 and Green house gas Protocol under Scope I and II emissions. The results revealed that the lean initiated apparel units had significantly lower carbon foot print in comparison to non- lean initiated units. Calculation of carbon footprint in this study is a valuable initiative towards reducing climate change impact.

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INTRODUCTION

Lean thinking must be "green" because it reduces the amount of energy, manufacturing space, and wasted by-products required to produce a given product. Indeed, examples are often cited of reducing human effort, space, and scrap by 50 percent or more, per product produced, through applying lean principles in a manufacturing facility.

Jim Womack (2003, para 1)

Lean production practices are generally not initiated for environmental reasons, but it is believed to bring about enhanced green or environmental performance as a by-product of lean principles (Naikwade, 2010). It's true that even when any organization embraces lean production system without keeping environmental goals in mind, its natural tendency is to move into green programmes automatically, further leading to reduced environmental impact as part of their drive to achieve the ever increasing leanness. Green manufacturing is more than just a coincidental side-effect, but, also a natural extension of lean. It not only serves as a catalyst but is also synergistic for green (Dües, Tan, and Lim, 2011).

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Hence lean manufacturers are significantly greener than the general population of manufacturers (Bergmiller and McWright, 2009). It is most likely that the lean transformation of any organization will result in a green transformation as well. As the essence of lean is to systematically reduce the deadly operational wastes, focusing on production costs, product quality, delivery and, workers involvement, which fits well with the strategy of protecting the environment by removal of green wastes as well. Lean waste is an activity that does not add any value to the product while the environmental waste is an unnecessary or excess use of resources or a substance released in the air, water, or land that could harm human health and the environment (Environmental Protection Agency[EPA], 2007). Most lean tools are also believed to support energy or environmental savings.

Lean is popularly known as "Performance without waste or Muda" (Bhatia, 2012, p.4). Hence, it becomes crucial to evaluate the lean manufacturing and production effectiveness in the form of performance after the identification and elimination of wastes. The improvements are measured in terms of various Key Performance Indicators (KPI), which are commonly used by all the manufacturing units to evaluate its overall success or the success of a particular activity in which it is engaged. To track, evaluate and document the environmental benefits as a part of lean implementation, one or more

environmental performance KPIs must be added and linked to the manufacturing performance. Typical metrics for measuring environmental performance include hazardous materials usage, water consumption, hazardous waste, water pollution, energy used, percent of energy from renewable resource, mass of finished goods per mass of raw material consumed, percent of raw materials re-used or used from recycled sources, CO_2 or greenhouse gas (GHG) emissions, and effluents or toxic substances discharged in waste, or lost (Krajnc and Glavic 2003; Kuriger *et al*., 2011; Langenwalter, 2006). Out of all these, calculation of CO_2 emissions which is also known as carbon footprint is the most complicated, and it's a challenge to measure and report it.

Literature review highlighted the sparseness of empirical evidence of the relationship between lean and carbon footprint, though there are few individual success stories showing the link between lean and green. Very few researches have dealt with the methodology and quantification of green house gas inventory of an apparel manufacturing unit. Keeping in view the importance of lean manufacturing in this competitive situation , this research was carried out to compare the environmental performance in terms of environmental key performance indicator carbon footprint among lean initiated and non- lean initiated apparel units in NCR in India.

MATERIALS AND METHODS

Ten lean initiated and non-lean initiated apparel units each in National Capital Region (NCR) in India were selected using inclusion or exclusion criteria from the member list of Apparel Export Promotion Council (AEPC), Gurgaon, India.

In order to facilitate comparison between apparel units, the sum total of CO_2 generated by the above fuels in terms of tonnes Co_2 e/year was divided by full time employees and annual turnover to get the values of the carbon footprint emitted (in tonnes) per full time employee and carbon footprint emitted (tonnes) per rupee earned. The data of these environmental key performance indicators of lean initiated and non–lean initiated apparel manufacturing units were statistically tested for its normal distribution using one sample Kolmogorov Smirnov test. The difference in data was found non-significant for carbon footprint per full time employee and carbon footprint per rupee earned demonstrating that the data was normal and hence t-test was used for analysis.

RESULTS AND DISCUSSION

The results of the study conducted with the aim of determination of the impact of lean adoption by the apparel manufacturing units on green house gas emissions through Carbon footprint as an environmental key performance factor are given below. No significant difference between lean and non-lean apparel units was found in terms of full time employees and annual turnover. As the sample was skewed, hence non-parametric test, Mann Whitney U test was used which revealed that the difference between the mean of full time employees and annual turnover between the two samples was non-significant as p-value was more than 0.05 for all the variables.

Table 1 gives the mean, standard deviation and Mann-Whitney U of full time employees and annual turnover of the apparel units.

H_a: There is a significant difference in performance in terms of environmental key performance indicator that is carbon footprint among lean initiated and non- lean initiated apparel units

The above stated hypothesis was framed with the aim of comparative assessment of the environmental performance of lean and non-lean initiated apparel manufacturing units in terms of carbon footprint. For reliable comparison between units, carbon footprint was assessed in terms of carbon footprint emitted (tonnes) per full time employee and carbon footprint emitted (tonnes) per rupee earned was used. Mean value of carbon foot print in Lean initiated units was found

Table 1. Mean, standard deviation, and Mann-Whitney u analysis of full time employees and annual turnover of the apparel units

Variables	Category	M	SD	Mean Rank	Sum of Ranks	U	p-value
Full time	Lean	754.30	526.99	12.20	122.00	33.000	.218ns
employees	Non-lean	618.20	796.20	8.80	88.00		
Annual Turnover	Lean	64.4	58.33	12.25	122.50	32.500	.190ns
	Non-lean	74.60	143.54	8.75	87.50		
	Non-lean	41217.20	40060.67	11.70	117.00		

Note. N=20 [Lean (10) and Non-Lean (10)].U= Mann-Whitney value. p-value <0.001=***.p-value<0.01=**.p-value<0.05=*. p- value>0.05=ns.

Table 2. Mean, standard deviation, and t- test analysis of carbon footprint in lean and non-lean initiated apparel manufacturing units

Variables	Category	M	SD	t-test		
				t	df	p-value
Carbon foot print per full time employee	Lean	0.78	0.46	4.44	18	.000**
	Non-Lean	2.38	1.05			
Carbon foot print per rupee earned	Lean	11.78	6.27	3.22	18	.005**
	Non-Lean	27.05	13.62			
	Non-Lean	.002	.001			

Note. N=20(10 Lean and 10 Non Lean).. t= observed or calculated t value; df=Degree of freedom. Sig. (2-tailed) =two-tailed p value associated with the test. p-value<0.001=***. p-value<0.01=**.p-value<0.05=*.p-value>0.05=ns.

lower in comparison to non -lean initiated units as shown in Table 2.

T-test analysis further revealed a statistically reliable difference between the mean of carbon footprint per full time employee as 0.78 and 2.38, t (18) =4.44 , p =.000**, at a significance level of 1% .The difference of carbon footprint per rupee earned was found in lean and non- lean initiated units as 11.78 and 27.05 respectively, t (18) =3.22 , p =.005**, α = .01; as expected lean initiated unit has lower carbon footprint per rupee earned than non-lean initiated apparel manufacturing unit. Alternate hypothesis (H_a) was partially accepted as p-value was>0.05 for two variables which implied that there was significant difference in the carbon footprint per full time employee and carbon foot print per rupee earned of lean initiated units and non-lean initiated units.

Similar results were found by Dües *et al*., 2011, which concluded that lean serves as a catalyst for green, meaning it facilitates a company's transformation towards green. Another research by Hibadullah, Fuzi, Desa, Zamri, and Habidin (2013) also found a significant relation between lean manufacturing practice and environmental performance in automobile industry. King and Lenox (2001) also provided empirical evidence about the adoption of environment management system as measured by the standard ISO 14001 by the apparel manufacturing units which had already implemented lean in terms of quality standard ISO 9001. Marudhamuthu and Krishnaswamy (2011) also associated that lean with lower emissions and concluded that more the establishment engages in lean, the lower will be its emissions. Results were in line with the research by Cordeiro *et al*., 2012 who concluded that lean and green had a curvilinear, u-shaped relationship instead of traditional assumption of a linear relationship. Kakkar (2012) also found the similar results in her research that lean reduces the carbon footprint.

Limitations of the Study

The study was limited to 10 lean initiated and non -lean initiated apparel units each manufacturing ladies garments in NCR. For the calculation of carbon footprint, only scope I and scope II emissions were counted, as in most of the apparel units record of data required for calculation of scope III carbon emissions was not maintained. Moreover, as inclusion of scope III emissions was optional as per Green House Gas (GHG) protocol, a relatively straightforward and low cost option of calculation was based solely on the year 2012 data. Time series analysis was not feasible as the data prior to 2012 was not collected.

Conclusion and Future Research

The environmental Key Performance Indicators (KPIs) helped in reporting the lean progress towards achieving the desired results. After the comparative performance assessment of lean initiated and non-lean initiated apparel manufacturing units in terms of KPIs, it was concluded that lean initiated apparel manufacturing units in National Capital Region showed better environmental performance in terms of carbon footprint than non-lean initiated apparel firms .Carbon footprint was found significantly lower in lean initiated units in comparison to non –lean initiated units. Keeping in mind the limitations of this research, a longitudinal study to measure carbon footprint of an apparel unit could be conducted and compared with the base emissions to know the reductions. Greenhouse Gas Inventory could be made for apparel manufacturing units including calculations of all three scopes of emissions to get the exact amount of emissions.

Terms

*L*ean Initiated apparel units are the ones which had initiated and adopted principles, tools, techniques and philosophy of Lean while non lean initiated units are those which are still following the traditional style of manufacturing.

Carbon footprint is the total amount of CO_2 and other greenhouse gases, emitted directly or indirectly over the full life cycle of a process or a product. It is expressed in grams/Kg/tonnes equivalent of CO_2, which accounts for the different global warming effects of the other greenhouse gases. The green house gases considered for calculating carbon footprint are carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, perfluorocarbons, hydrofluoroethers and sulphur hexafluoride.

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