Lean Manufacturers' Transcendence to Green Manufacturing

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Abstract

A survey was administered to manufacturers recognized by the Shingo Prize as Lean to determine if they are transcending to a Greener state because of their commitment to Lean production. Results were compared with data published by Melnyk, et. al. [5] regarding the Greenness of over 1100 general manufacturing plants. The companies recognized by Shingo score significantly higher in Greenness than the manufacturers studied by Melnyk, et. al. This suggests that Lean companies are embracing Green objectives and transcending to Green manufacturing as a natural extension of their culture of continuous waste reduction, integral to world class Lean programs.

Keywords

Lean Production; Green Operations; Efficiency; Environment; Sustainability; Waste Reduction

1. Introduction

One key principle of Lean production is the reduction of wasted materials and labor in a continuously improving culture [4]. To see if Lean companies naturally tend to be Green, known Lean manufacturers were surveyed to determine if they were transcending to a more Green state as a result of their commitment to Lean production. The Lean manufacturers included in the study were plantsites that received site visits from the Shingo Prize team during the years 2000 through 2005 as part of the process of applying for the Prize. This sample was 120 individual manufacturing plants, from which 47 usable surveys were received [1]. The data from this sample was compared to similar data published by Melnyk, Sroufe, and Calantone [5] regarding the Greenness of roughly 1100 general manufacturing plants in the US.

Variables in the study were numerous, including measures of Green Management System, Green Waste Reducing Techniques, and Green Results as first defined by Melnyk, et. al. [5] Measures of Leanness were derived from Shingo Prize evaluations of the plants [7]. Our results are staggering in that Shingo companies score significantly higher than the general population of manufacturers studied by Melnyk, et.al. in 25 out of 26 Green measures (GMS, GWRT, and GR). This makes a very powerful statement that Lean companies are embracing Green objectives and suggests that Lean manufacturers are transcending to Green manufacturing as a natural extension of their culture of continuous waste reduction, integral to world class Lean programs.

2. Theoretical Model and Hypothesis

2.1 Model of Advanced Green Systems

Significant agreement amongst researchers shows there are three major components to a theoretical model of Green Operations Systems [3]. Top management commitment comes in the form of Green Management Systems (GMS) with policies and procedures empowering employees to make decisions based on reduced environmental impact. This commitment is the beginning point in establishing Green organizations. GMS will support an organizational culture that identifies sources of environmental wastes and implements Green Waste Reduction Techniques (GWRT) designed to reduce the types and amounts of environmental wastes generated by the company's operations. The implementation of GWRTs leads to improvements in business metrics of Green Results (GR). The Advanced Green

System Model [3], which is developed from several leading theories, is reproduced here in Figure 1. The figure shows the individual elements comprising the GMS, GWRT, and GR.

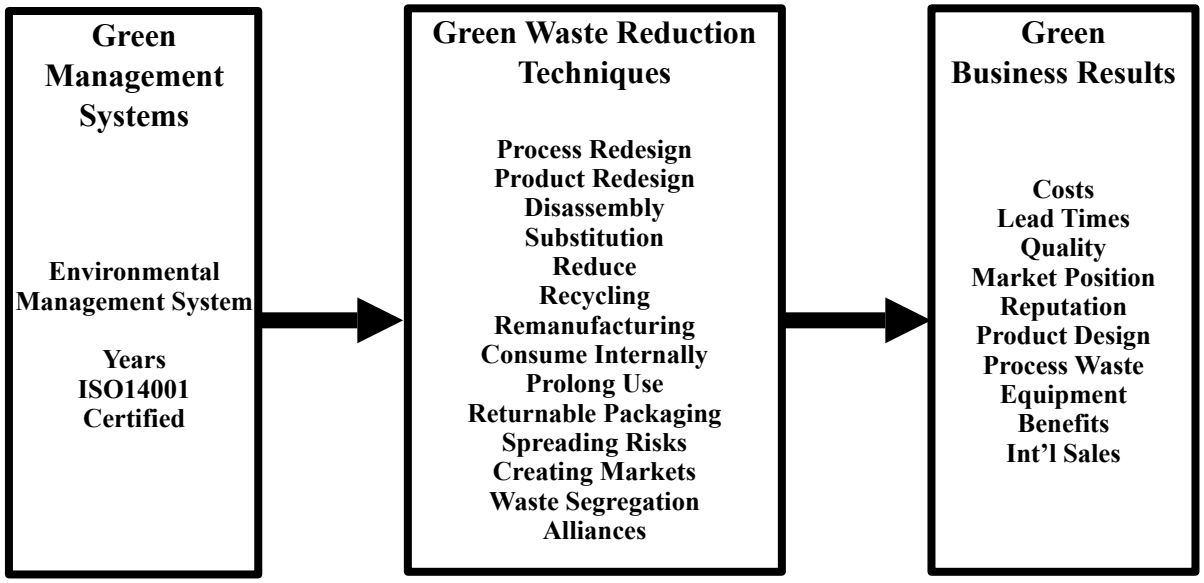

Figure 1: Advanced Green System Model, from [3]

2.2 Hypothesis

Lean Production Systems are founded on the idea of building organizational efficiency by obtaining as much or more production from consuming less resources (primarily materials and labor) [4]. Lean Production Systems have structures very similar to Green Operations Systems in that both involve management systems, waste reducing techniques, and business results [3]. These two facts suggest that an organization that has successfully implemented Lean would have developed Lean Management Systems (LMS) similar to Green Management Systems. Such an organization would have learned to identify Lean wastes and to implement Lean Waste Reduction Techniques (LWRT) in order to achieve Lean Results (LR). To see if, in fact, organizational success at implementing a Lean System leads naturally to achieving some of the success of a Green System, we establish the following hypothesis:

Lean manufacturers are significantly Greener than the general population of manufacturers.

If this hypothesis is shown to be true, we can conclude that significant Lean Production Systems implementation makes a contribution to achieving some of the results targeted by Green Operations Systems. If this is true, we can also surmise that Lean manufacturers may transcend into Greenness without that specific goal in mind. In other words, a natural movement towards reduced environmental impact may be a result of Lean Programs.

Testing this hypothesis requires the comparison of Lean manufacturers to a general group of manufacturers not specifically noted as Lean and it requires valid measures of both Leanness and Greenness. The most objective, valid, and comprehensive measuring of Leanness is found in the Shingo Prize criteria as administered by a select, trained team of examiners who score companies applying for the Shingo Prize in Manufacturing Excellence [1,7]. Receipt of the Shingo Prize is the highest recognition of Leanness available today and companies evaluated by the Shingo Prize team have known levels of Leanness and may be stratified on this basis. All companies receiving site visits (and therefore complete evaluation) from the Shingo Prize Evaluation Team in the years 2000 through 2005 (120 companies) comprised the set of Lean manufacturers for the study. The general population of manufacturers was represented by more than 1100 companies involved in the Melnyk study [5] and for whom published data was available. The population chosen for their survey was based on accepted industry data bases of manufacturers and filtered to assure they were discrete manufacturers, in sectors likely to implement environmental management systems. Melnyk's study looked at the relationship between strength of Environmental Management System (EMS) and business results, but did not evaluate Leanness in any way [1]. Because Leanness is not a factor in drawing this sample and is not measured by the study, this population is a good sample of all manufacturers. Melnyk also

used a comprehensive number of Green variables to measure the strength of EMS, use of GWRT, and achievement of various business results. The collection of data comparable to Melnyk's from the known Lean companies allowed statistical comparison of the two data sets to determine if the hypothesis was proven.

3. Methodology

3.1 Survey Development

The survey instrument developed and tested by Melnyk, et. al. [5] was adapted for use in this study. Consistent with the three main manufacturing system components, the survey has three sections (GMS, GWRT, and GR). The first section of the survey (GMS) addresses the status and maturity of the plant's environmental management system implementation. The second section (GWRT) is comprised of fourteen questions regarding specific practices the plant undertakes to reduce environmental waste. The third section (GR) is comprised of ten questions that address the process and business results of Green manufacturing efforts in the plant. The survey questions align directly with the Green dependent variables shown in the Advanced Green System Model in Figure 1. Details of the survey construction and validation are beyond the scope of this short paper, but may be found in Bergmiller [1].

3.2 On-line Survey Development

The Shingo Prize team generously provided access to the Shingo database and assisted with distributing an invitation to all companies in the study group to participate. The survey was formatted to an on-line survey processor and companies in the "Lean" group were sent a link to the website along with encouragement from the Shingo Prize Committee to complete it. Responses from the on-line survey were connected with the Shingo evaluation scores by the use of a privacy code [1].

3.3 Data Analysis

The unit of analysis for this study is the individual manufacturing plant because two of the major externally validated measures (Shingo prize site visit scores and ISO14001 certification) are administered at the plant level. A total of one hundred-twenty plants were invited to take the survey of which fifty-one plants responded, and forty-seven responses were usable, giving a survey response rate of thirty-nine percent [1].

Reliability of the data sets was confirmed using Cronbach's coefficient Alpha tests and repeating findings from previous Lean and Green studies. Hotelling's T-test was utilized to test the hypothesis. Pearson's product moment correlation coefficients were utilized to determine significant correlations between all variables in the study. Regression analysis was utilized to determine multi-variant effects on study variables [1].

4. Results

4.1 Validation

The Cronbach coefficient Alphas for all variables utilized in the study exceeded the 0.70 reliability coefficient threshold [6] indicating acceptable reliability of the entire data set. The Pearson product moment correlation test showed significant correlation between LMS and LWRT, LWRT and LR, GMS and GWRT, and GWRT and GR [1]. These two tests show that the data set, though somewhat small, is statistically significant. As has been mentioned earlier, previous studies of Lean and Green systems have shown them to be philosophically, theoretically, and structurally similar [3].

4.2 Hypothesis Testing

The hypothesis compared the Green survey statistics of the Shingo plant survey respondents to the statistics of the general population of manufacturing plants surveyed originally by Melnyk et. al. [5].

The T-test analysis for the hypothesis is given in Table 1 [1] and provides strong statistical evidence that the known Lean Shingo companies are significantly Greener than the general manufacturing population. In twenty-five of the

Table 1. T-Test Results for Hypothesis

			Melnyk			Shingo		Significance		
Factor	*Label*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	*t*	*p*	Significance
ISO14001 certified	GMS1	1510	0.083		47	0.787	0.225		*Meaningful difference*	
Years certified	GMS2	1510	0.917		47	3.574	2.842		*Meaningful difference*	
Product redesign	GWRT1	1163	2.996	1.228	42	3.619	1.011	3.248	0.0012	**
Process redesign	GWRT2	1166	3.380	1.164	46	4.174	0.769	4.586	0.0000	****
Dissassembly	GWRT3	1155	2.612	1.208	42	3.024	1.239	2.168	0.0303	*
Substitution	GWRT4	1163	3.408	1.220	47	4.128	0.924	3.997	0.0001	****
Reduce	GWRT5	1160	3.328	1.212	46	3.978	0.830	3.605	0.0003	***
Recycling	GWRT6	1165	3.192	1.276	46	3.826	1.180	3.315	0.0009	***
Remanufacturing	GWRT7	1148	2.664	1.248	41	2.902	1.261	1.202	0.2297	
Consume Internally	GWRT8	1163	2.464	1.196	42	3.000	1.230	2.851	0.0044	**
Prolong Use	GWRT9	1154	3.004	1.592	44	3.545	1.170	2.233	0.0258	*
Returnable Packaging	GWRT10	1162	3.324	1.292	47	4.191	0.970	4.551	0.0000	****
Spreading Risks	GWRT11	1153	2.776	1.156	42	3.262	1.061	2.683	0.0074	**
Creating markets	GWRT12	1156	2.696	1.228	40	3.175	1.412	2.413	0.0160	*
Waste Segregation	GWRT13	1161	3.212	1.220	45	4.378	0.806	6.355	0.0000	****
Alliances	GWRT14	1154	2.984	1.220	47	3.723	1.057	4.092	0.0000	****
Reduced costs	GR1	1142	2.340	1.028	47	3.915	0.855	10.355	0.0000	****
Reduced lead-times	GR2	1143	2.084	0.912	42	3.095	0.821	7.081	0.0000	****
Improved product quality	GR3	1144	2.296	1.012	46	3.435	0.981	7.492	0.0000	****
Improved market position	GR4	1140	2.392	1.080	47	3.638	0.819	7.818	0.0000	****
Enhanced reputation	GR5	1144	2.940	1.236	47	4.298	0.623	7.490	0.0000	****
Improved product design	GR6	1144	2.440	1.108	45	3.622	0.886	7.068	0.0000	****
Reduced process waste	GR7	1144	2.892	1.196	47	4.191	0.798	7.380	0.0000	****
Improved equipment selection	GR8	1133	2.608	1.116	47	3.745	0.793	6.909	0.0000	****
Benefits outweigh costs	GR9	1138	2.684	1.132	46	3.935	0.680	7.438	0.0000	****
Improved international sales	GR10	1133	2.492	1.156	47	3.872	0.824	8.100	0.0000	****

Significance *P<0.05 **P<0.01 ***P<0.001 ****P<0.0001

twenty-six measures of Greenness*, the Shingo companies are significantly Greener, at $P<0.05$ level of significance. Nineteen of the measures have a significance level of $P<0.01$. For Green Results (GR), in all cases the significance is $P<0.0001$, the highest practical level of statistical significance. The significance levels for the Green Results are much higher than the significance levels for the Green Waste Reducing Techniques (GWRTs). Yet, we know that the GWRTs strongly correlate to GR variables. This suggests that Lean plants that implement GWRTs are realizing disproportionately better results of their Green efforts than the general population. This also suggests there may be synergy between Lean and Green efforts within the Shingo plants. That is to say, plants that commit themselves to Lean best practices not only realize strong Lean Results, they also realize better results from their Green best practices than the general population. [1]

5. Discussion

The logical explanation for this finding is that Lean plants have a well-honed infrastructure for identifying and eliminating waste, through total employee involvement and continuous improvement. If Green wastes were identified as opportunities for improvement, the efficiency by which Lean plants would reduce these wastes and generate measurable Green results, would logically be much higher than a plant without the Lean culture. Often it is the case in non-Lean plants that "band-aid" solutions are deployed to address an environmental symptom. Lean plants possess a disciplined approach to problem solving that gets to the root cause of the problem efficiently and implement systemic solutions that yield sustained results.

The findings of this study provide strong evidence of transcendence to Green manufacturing by leading Lean manufacturers. It is clear from the statistics that the level of adoption of both Lean and Green best practices are very high across the board for the Shingo companies. This is clear evidence that Lean companies are implementing Green manufacturing systems. This suggests that they may be taking a holistic view of waste elimination that includes both Lean and Green wastes. The findings also suggest evidence of synergy between the two systems.

6. Conclusions

6.1 Known Lean plants are significantly Greener than the general manufacturing population.

The survey statistics of the Shingo plants in this study were compared to the survey statistics from the original Melnyk study [5] which surveyed the general manufacturing population. The results indicate that the Shingo plants were significantly Greener in all but one of the twenty-six Green manufacturing system measures. These findings provide strong evidence of *transcendence* to Green manufacturing by leading Lean manufacturers. For all ten Green Results variables, the Shingo plants were significantly higher, at the $P<0.0001$ level, than the general population. This is disproportionate to comparison of statistics of Green Waste Reducing Techniques between Shingo and Melnyk plants. This suggests that having a Lean system infrastructure serves as a catalyst to the successful implementation of Green best practices and the achievement of corresponding Green Results. The evidence that plants with Lean systems yield higher Green Results supports the philosophical notion of Lean and Green synergy.

6.2 Further research into the synergistic relationship between Lean and Green Systems offers much potential for improving the effectiveness of both.

The results of this study show that firms embracing Lean Production Systems will have a natural tendency to move into Green programs as part of their drive to achieve ever-increasing Leanness. The philosophical and structural similarities between models of Leanness and Greenness suggest that the reverse may also be true; i.e., those firms seeking minimal environmental impact from their operations may naturally adopt some methods of Lean Production in order to reduce wastage. Indeed, some work in this area is already yielding provocative results [2].

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* The one Green variable that was not significant in this study was Remanufacturing, a "Lean" technique of rebuilding a defective product rather than scrapping it. This is a relatively rare and advanced technique that is not in wide use today. Intuitively, use of remanufacturing will reduce the amount of waste generated by the production system; however, the rarity of its use by the companies in our sample resulted in a lack of significance.

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