
The Eco Lean method – A combined approach for low cost economic and ecologic optimization in the manufacturing industry

Robert Miehe*, Ivan Bogdanov², Ralph Schneider³, Marius Hirsch³, Thomas Bauernhansl³, Elzbieta Pawlik⁵, Remigiusz Horba⁴

*Fraunhofer-Institute for Manufacturing Engineering and Automation (IPA), Nobelstr. 12, 70569 Stuttgart, Germany
²Lean Enterprise Institute (LEI), ul. Muchoborska 18, 54-424 Wroclaw, Poland

* Corresponding author. Tel.: +49(0)711/970-1424; fax: +49(0)711/970-1002. E-mail address: Robert.Miehe@ipa.fraunhofer.de

Abstract

Rising resource efficiency is essential for a future green economy. Research and business activities in this field have thus increased dramatically during the past decades. While most environmentally oriented methods suffice to provide deep transparency, few have the ability to depict optimization potential and/or provide procedural methods of improvement. The general approach of ecological amendments in industries thus often is investment intensive. Numerous companies however do not dispose of appropriate savings. These companies strongly depend on low cost improvements, a field that has yet been neglected in research.

In this paper we present a tailored approach for low cost economic and ecologic optimization of manufacturing processes. Therefore, we discuss conflicts and links between characteristic ecological and Lean principles in order to develop a greater Eco Lean mindset. Adopting the Lean philosophy, to do more with less, we introduce a four step approach. Therefore, we expand the traditional understanding of lean waste categories by adding ecologically relevant problem areas. In a first step, the orbit view, economic and ecologic wastage is determined via advanced Gemba walk that consists of visual testing and selective interrogation. We use a plant layout and specific characters to map areas of waste within a production facility. Hereupon, a weighting of problems is executed based on expected effort for implementation and impact on waste reduction. A single problem then is analyzed extensively in order to determine its value adding, organizational and waste tasks. In a final step we chose an appropriate method for optimization based on the specific problem.

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1. Introduction

Greening the global economy is fundamental for a future well-being of societies. In the last 30 years global resource consumption doubled, resulting in an aggregated growth rate of 118%, yet being exceeded by the growth rate of important metals of 147% [1]. A continuation of this trend eventually leads to another doubling until 2050 [2]. This excessive use of resources due to traditional production and consumption patterns has led to various major and minor dangers for todays and future generations and the environment, e.g. resource scarcity, climate change [3]. Natural resources, however, set the basis for most economic activities. Accessibility thus is an essential aspect of future well-being [4]. Governments have introduced a variety of policies and programs in order to realize a resource-efficient economy, e.g. German Resource Efficiency Program [5], Resource-Effective Europe Flagship Initiative [6], Thematic Strategy on the Sustainable Use of Natural Resources [7], and European Resource Efficiency Platform [8].

Commonly, three strategies are quoted when discussing sustained resource utilization: efficiency, sufficiency and consistency/effectiveness [10]. Therefrom, solely resource efficiency may be partly determined in production, while especially sufficiency and consistency/effectiveness are based decision making during product design and consumption.
While political approaches are sustainability oriented, a company’s commitment towards resource efficiency is largely cost driven at present. Companies thus have to be decoyed with economic benefits in order to implement a multiplicity of sustainability measures. As cost of material cause roughly 45% of total costs in the German processing industry [9], companies have especially identified material efficiency as a powerful operating lever.

Although sustainability has been discussed for almost three decades, one prejudice remains in industries: increasing sustainability causes high investments and long payback periods [15]. This assumption is partly based on the lack of a holistic improvement approach. In an economic context, Lean Management provides such a holistic approach that enables companies to identify and solve problems. Ecology oriented methods, e.g. Life Cycle Assessment (LCA), in contrast, are designed to create detailed transparency regarding the environmental impact of a certain action. Methods that enable organizational improvement of ecological parameter are, however, rare.

In this paper we discuss similarities and discrepancies of Lean Management and Ecology in order to detect an integrated philosophy that again allows the derivation of certain mind-setting principles. The here presented approach aims at improving a company’s economic and ecologic performance significantly via low-cost organizational enhancement. We thus develop an optimization procedure and present instrumental methods and tools for improvement.

2. State-of-the-art

Various authors have discussed the applicability of Lean thinking in order to improve a company’s environmental performance [11–14]. In this context, the “Lean and Green” label has evolved. The US EPA presents a toolkit that among others estimates environmental impact of Lean waste reduction, identifies Lean approaches as potentially beneficial and demands ecologically oriented Kaizen shop floor workshops [16]. Other authors focus on certain Lean related methods and aim at extending its application to environmentally related aspects. Hereby, especially the method of value stream mapping (VSM) depicts a foundation of advancement. Erlach and Westkaemper, Faulkner et al., Erlach and Sheehan, and Rieder et al. add various ecology related aspects to the analysis, e.g. resource use, energy consumption, CO₂ emissions [17–20].

The transfer to an environmentally friendly value stream design (VSD) yet is vague. Chiarini provides an overview of the environmental impact of various Lean related methods in the context of European motorcycle component manufacturers [25]. Hereby, VSM, 5S, Cellular manufacturing, and TPM are identified as beneficial, while Single Minute Exchange of Die (SMED) is not found to add benefit to the environment.

The overall assumption of these studies that a reduction of Lean waste categories ultimately leads to environmental benefits, however, is rarely questioned. In fact, few studies exist that provide an extension of traditional Lean waste categories by adding environmentally related wastage, e.g. energy consumption, emissions [21–23], yet these definitions lack of scientific foundation. Venkat and Wakeland show that especially frequent replenishment and long distances of delivery of JIT/JIS strategies have negative influence to the environment [28].

While Lean provides a holistic, self-contained framework that covers a certain philosophy as well as various methods and tools for creation of transparency and improvement, the ecological opposition lacks of such. Solely, the notion of sustainability introduced in 1987 offers few projections. The application of its most common interpretation – the three pillar concept of economy, ecology and society - is, however, hampered due to its ambiguous phrasing. We thus conclude that the majority of studies focus on the single method level. The hereby claimed environmental benefit is based on different assumptions. We thus classify the existing environmentally oriented extension of waste categories as inappropriate. The “Lean and Green” discussion lacks of an holistic approach that provides a uniform understanding of ecology, an overall philosophy as well as conflict free principles, methods, and tools.

3. The ecology of Lean management – A comparison

We understand the term ecology as a synonym for environmental conservation. Nature hereby does not only serve human satisfaction but exhibits the right to exist on its own terms. As such, the idea of ecology significantly differs from the traditional Lean thinking in terms of goal, scale, scope, identification of potential improvements, impact, and results. The goal of Lean Management is an increase of human customer satisfaction [24]. It therefore intends to eliminate or reduce every activity to a minimum that does not generate value in the eyes of the customer. Reduction of resource consumption, however, remains a side effect of the application of Lean methods [23,26]. In comparison, ecologically oriented actions focus on not using natural resources at all [27]. The mandatory requirement of Lean - to use resources in order to satisfy the customer - is thus inconsistent with environmental conservation. In terms of its goal both approaches hence are fundamentally different [28].

The scope of both approaches likewise differs. While Lean management represents a process-orientated approach [24], environmental conservation demands for an improvement of products and processes [29]. Lean design solely focusses on the reduction of development time but never questions the resources that are used to produce the product itself [30].

Ecologically oriented actions, in contrast, require an analysis of environmental impact [16]. Therefore, different system boundaries boarders are possible, e.g. cradle-to-grave, cradle-to-gate, gate-to-gate, gate-to-consumer. Several further differences can be found regarding the scale of the two approaches. Lean management is labeled a holistic approach due to its focus on process improvements within the supply chain and the company [24,31]. Its leverage, however, ends when the product is handed out to the customer [31]. Assuming life-cycle thinking for a single product, ecology considers both upstream and downstream stages, e.g. usage, end-of-life [32].

Another aspect of comparison is the approach to identify potentials for improvement. In the context of Lean
management, an assessment of wastage is conducted [24]. While literature differs between different types of waste (see 4.3), the course of action remains identical: 1. analysis of current state of value adding of each activity; 2. comparison with target state; 3. elimination/reduction of all non-value adding activities [24]. In contrast, ecological improvement requires a simultaneous realization of three of strategies: conservative handling (resource efficiency), reduction of impact of used resources (resource effectiveness), and reduction of consumption (resource sufficiency). Lean comprises methods and tools for problem identification and solving, while in the context of ecology methods simply aim at achieving greater transparency. Methods for problem solving are rare.

Finally, Lean management focuses on comparatively fast, low-cost implementation of actions in order to solve a given problem [24]. This mainly results in enhancements of process stability and reduction of the lead time [33], whereas the quality of a given product remains the same. In contrast, the implementation of ecologically oriented actions generally results in a reduction of resource use and impact during the entire life-cycle [32].

Concluding, Lean and ecology exhibit both a variety of intersections and differences. A simple combination of both stringent approaches thus is not possible. A leading philosophy is required. As ecology exhibits the larger scale, it should depict the premier selection. This, however, would lead to significant restrictions to economic activities. In this paper, we thus choose Lean as the leading philosophy. The combination of both approaches, however, requires amendments on either side. We thereby assume that environmental conservation, even if not explicitly expressed, represents an implied customer requirement.

4. The Eco Lean approach

Eco-Lean represents a holistic approach for a combined economic and ecologic low-cost improvement in the manufacturing industry that consists of a mindset as well as principles, methods and tools. The term low-cost improvement thereby is understood as an organizational enhancement of the manufacturing process in small steps (Kaizen) via minor investments. A concrete cap of investment cannot be defined, although it should not exceed a low level five digit Euro value. The payback period of such measures should not transcend three years. Improvement measures may thus be classified as low cost if either one of the following criteria is met:

1. The enhancement action can be executed without additional costs to the company. Costs that accrue in any case, e.g. employee salary, are not considered.
2. The investment of an enhancement action does not exceed a low level five digit Euro value.
3. The payback period of a higher investment does not exceed three years.

The following subsections describe derivation and formulation of each aspect of the Eco Lean approach.

4.1. The Eco-Lean philosophy

We choose Lean management as the leading philosophy for an integration of ecology. The overall target hence remains the satisfaction of customer needs and may be summarized as follows: To provide a customer with the desired product in the required quality and time. The major question, however, is how far ecology has to play to the Lean philosophy. In the Eco Lean understanding customer requirements are not exclusively expressed directly but indirectly implied. This especially refers to environmental conservation. In contrast to the traditional Lean understanding, time and stability are not accepted as unique measures. Eco Lean demands quickness, stability and resource efficiency. Improvement measures shall solely be implemented if the resource efficiency constraint is fulfilled. For instance, a measure that improves time but downgrades resource efficiency should not be implemented. While this remains the single restriction to the Lean philosophy, ecology can solely be considered gate-to-gate.

4.2. Eco-Lean principles

Organizational implementation of a holistic improvement approach requires certain standard settings that function as action guidelines. We therefore deploy the traditional Lean understanding of Pfeiffer and Weiss [24]. Hereby, a differentiation is made between content and process related principles. The latter are further grouped in methodological and attitude related settings, as summarized in Table 1.

Table 1. Eco Lean principles in dependence on Pfeiffer and Weiss [24]

<table>
<thead>
<tr>
<th>Process related principles</th>
<th>Attitude related principles</th>
<th>Content related principles</th>
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</thead>
<tbody>
<tr>
<td>- Task identity: Necessity of identifying cause-effect relationships between input, output, employees, material expenses, and organization in order to fully understand a problem</td>
<td>- Factual instead of monetary level orientation and acting</td>
<td>- Human capital dominates equipment capital (Increase profit of employee manpower instead of aiming at reducing employee costs)</td>
</tr>
<tr>
<td>- Process orientation</td>
<td>- Continuity and consequence in thinking</td>
<td></td>
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<tr>
<td>- Complex planning</td>
<td>- Implementation of orientation instead of</td>
<td></td>
</tr>
<tr>
<td>- Decentralization</td>
<td>- Avoidance of waste</td>
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<tr>
<td>- Customer orientation</td>
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From an ecology perspective three principles have to be restricted, while the others may remain unaffected. Eco Lean influences the understanding of waste avoidance, customer orientation and the content related principle. For the former certain environmentally related wastages are defined (see 4.3), whereas customer orientation is extended by the inclusion of indirectly expressed customer needs. In addition, we impose human and nature capital over equipment capital.
4.3. Eco-Lean waste categories

Traditionally, Lean Management differs between seven waste categories: transport, inventory, motion, waiting, over-engineering, over-processing, and defects (TIMWOOD) [34]. Various authors have extended this understanding by adding products that do not correlate with customer needs, unused employee productivity and knowledge, and non-demand for normal performance [35,36]. In the “Lean and Green” context, additional approaches have been published that aim at implementing environmental aspects, e.g. energy consumption, emissions. The US EPA defines environmentally relevant wastage as an unnecessary or excessive use of resources or substances [16]. A differentiation of the term excessive is, however, not provided. Likewise arguments can be found in a variety of other studies [37–39]. This nonspecific boundary of harm to the environment depicts a general problem of integrating economic and ecologic measures into a single solution. Ecology’s premier target is to harm the environment in no way. Consequential, two ancillary goals can be derived: no use of resources and no emissions. From a manufacturing perspective, a complete abandonment of resource use is not possible. Instead, four operating levers can be defined in the order of priority that aim at reducing the impact of resource use and emissions:
1. Minimization of environmental impact by choice of resource type
2. Minimization of resource use (quantity)
3. Minimization of environmental impact by choice of emissions type
4. Minimization of emissions (quantity)

While decisions about type generally are made during the design phase, solutions may be partially implemented during the manufacturing of a product, e.g. end-of-pipe solutions. Based on the operating levers, three categories of ecologic waste categories can be derived for every stage of a product’s life-cycle. First, the quantity of bound resources within a product has to be reduced. This sufficiency related strategy rather depicts a design task. Eco Lean thus does not focus on bound resources but defines environmentally relevant waste as each and every resource that leaves the contemplated system (gate-to-gate). Hereby, lost, additional, and critical resources may be differed. Lost resources are understood as quantity losses due to inefficient processes, whereas additional resources are used for packaging and the like. These type of resources in no way tackle a customer desire and are consumed directly during unpacking. Critical resources describe the use of resources that are ecologically risky and/or hardly reusable.

4.4. Eco-Lean optimization procedure

The Eco Lean optimization procedure follows four standard stages as illustrated in Fig. 1.

The first step aims at achieving transparency with little effort. Its goal is to initially identify obvious problem areas. Therefore, an advanced Gemba walk has to be conducted on the shop floor. In contrast to the traditional approach, additional aspects have to be examined as well, e.g. loss of resources. We therefore propose the usage of a plant layout in order to roughly delineate facility installations, breakdown of divisions, work flows and problem areas. Selective interrogation with facility employees provides additional information, e.g. machine performance at different load levels, problems with a certain machine. A secondary part of orbit view is a data analysis regarding ecological performance. Therefore, the utilized resources have to be classified in type and quantity of consumption over a previously defined period of time. Suitable sources among others are energy and material bills, supplier contracts, and standard reports (e.g. ISO 9001, 14001 and the like). In a final step, consumption data have to be allocated to certain divisions or products. If a direct assignment of consumption is not possible, allocation rates have to be developed.

After initially identifying problem areas, a prioritization has to be made in order to detect major and minor preferences. A holistic implementation of Eco Lean, however, tackles each and every problem striving to the best possible scenario. Nevertheless, essential problems should be counteracted first. Therefore, we propose a weighting of problems regarding its impact on waste reduction and expected effort for implementation. Fig. 2 illustrates the approach.

After the decision to focus on a particular problem, its root cause has to be identified. This step focuses on achieving the highest possible level of transparency. In a final step, we then seek for improvement. We therefore propose a problem solving
procedure in eight steps based on the traditional A3-Report, as displayed in table 2.

Table 2. Root cause analysis and improvement procedure in dependence on the traditional A3-Report.

<table>
<thead>
<tr>
<th>Root cause analysis</th>
<th>Improvement procedure</th>
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<tbody>
<tr>
<td>1. Appoint problem</td>
<td>5. Set goal</td>
</tr>
<tr>
<td>2. Describe background</td>
<td>6. Develop implementation plan</td>
</tr>
<tr>
<td>3. Describe current situation</td>
<td>7. Agree upon follow-up actions</td>
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Especially in the context of combining Lean and Ecology, the analysis of the root cause (point 4) depicts a challenge. Depending on the type of problem various tools for analysis are possible, e.g. stability, flow, impact, and task analysis (identification of value and non-value adding activities).

5. Discussion and conclusion

Lean management has become a wide-spread approach in industries in order to optimize manufacturing processes. With increasing perception of environmental problems, e.g. climate change, resource scarcity, the Lean and Green label has been developed aiming at improving environmental performance via Lean methods. Although various authors have discussed possible applications and benefits, a combined philosophy has not yet been developed. Existing studies thus lack of scientific foundation.

In this paper we presented the Eco Lean approach. Therefore, we discussed intersections and differences between the Lean philosophy and ecology – understood as environmental conservation. In this understanding, a combination of both stringent approaches was not possible. We identified Lean to be appropriate as the leading philosophy and hereupon developed a combined approach. Its premier distinguishing feature is the understanding of customer requirements. While the traditional Lean approach is oriented toward directly expressed customer needs, we assume environmental protection to be an indirectly imposed consumer requirement. Time and stability are thus not accepted as unique measures. Eco Lean demands quickness, stability and resource efficiency. Improvement measures shall solely be implemented if the resource efficiency constraint is fulfilled. Besides customer orientation, this understanding restricts the traditional Lean thinking in two additional principles: waste avoidance and capital focus. While resource type is determined in the design phase, quantity of resource use and its related emissions may be partially reduced during the manufacturing of a product, e.g. end-of-pipe solutions. We thus define three waste categories: Lost resources (quantity of not bound resources that leave the system border), additional resources (packaging and the like), and the use of critical resources (ecologically risky and/or hardly reusable).

This understanding requires an amendment of essential Lean related methods and tools in order to integrate the resource efficiency constraint. We therefore presented a four step optimization procedure that follows the traditional Lean understanding of problem solving. Our future research will focus on the amendment and adaptation of Lean and ecology related methods in order to deliver a holistically consistent concept of industrial behavior that enables extensive ecological improvement.

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References


