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Green Lean

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Abstract: This literature review is focused on the comparison of Lean and Green practice and how the two practices correlate to each other in different contexts. One major context is manufacturing where the strongest relationship is identified. Supply chain is examined from different aspects, such as supply relationship and Life Cycle Assessment. Managing the lean and green supply chain is one of the focused areas, where implementation and barriers are identified. The scientific literature was collected mainly in Google Scholar.

Keywords: Green, Lean, Manufacturing, Supply Chain, Environmental performance.

1 Introduction

Climate change and the pressing issue of energy efficiency is challenging and shaping the business world. Supply chains and energy security is identified as a few of the key aspects that will fundamentally shape the future. Companies are facing pressures to reduce the energy consumption and reducing the emissions of carbon and other greenhouse gases. The pressures can derive from customers and even from governments. A transition toward lowering the need for energy is noticed in the business world (Halldórsson & Kovács 2010).

Lean manufacturing systems are well known thought Likers (2004) fourteen principles, a result from twenty years of studying Toyota, and from Womack and Jones (1996) among others, who studied the automobile manufacturers in Japan as early as mid-1990's. Environmental Management Systems (ISO14001) have more recently become a part of the Management System standard. This standard is based on a management point of view, where the organisation's management identifies regulated and unregulated environmental aspects as well as impacts of the company's operations. These aspects can be of human or industrial activities, or

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products and services that in some way affect the environment. Evaluation can be based on what impacts or changes the activities can cause. When identified, the management can set goals and plans for the organisation regarding environmental improvements. This process leads to an integration of the environmental management with the overall management of the organisation, and results in a continual improvement cycle (ISO, 2002).

The aim of this literature study is to investigate if there is a correlation between lean and environmental systems, to find out if Green and Lean programs are linked to each other. Lean manufacturing is of interest as well as Lean supply chain, the later for broadening the scope and to set Green programs in a greater context. An important aspect is to analyse how management in all areas can influence each other and in which areas. So how do the strategies correlate in the identified aspects and what benefits or disadvantages does the possible correlations entail?

2 Method

Relevant scientific articles included in this literature study where collected on the scientific research database Google Scholar, as well as on DIVA and Mälardalens University library where dissertations were found. Found literature was selected and reviewed with the aim of no preconceptions regarding to the content, as long as the research was within the scope of this study. Although it is difficult to exclude preconceptions entirely, efforts to do so was prioritised.

One particularly important criteria for relevance of the study was that the articles should not be older than 2000, preferably from 2005 and later. During an initial search abstract from found articles were read to decide if the article were within the scope of this literature study. After this stage articles were read through in their whole, specially focus was laid upon results of the findings. Used search words were Green, Lean, Supply Chain, Logistic, in different combinations until appropriate number of articles where found. In some cases, the found articles did not provide relevant information, but did however contain interesting references to articles that was of interest. In those cases, the references were found and included in the literature study.

3 Literature study

The literature study is started off by the comparison of *Lean and Green Programs* to identify common factors and correlation of the programs. *Lean and Green Manufacturing* is followed and the terms are presented in realtion to production and manufacturing. Lastly *A Green and Lean Supply Chain* is presented, here a section on management is also included.

3.1 Lean and Green Programs

When applying Green practices in Lean companies, the company will achieve better Lean results compared with companies that do not apply Green. Best results and full potential from the separate practices are realised with simultaneous implementation (Bergmiller & Mccright 2009). When applying lean production methods and reducing internal waste, companies that have successfully done so are likely to implement practices for environmental management and thereby broaden the scope of waste reduction besides from the efficiency aspect (Yang et al. 2011). Environmental management and improvements in the manufacturing system has a positive correlation and have effects in quality management, lean manufacturing practice and involvement of the employees. Befits are also related to both environmental and manufacturing technologies (Simpson & Power 2005).

A company that applies Lean manufacturing programs can get better results concerning reduced costs, increased efficiency and faster customer response time. Green programs can on the other hand improve a company's waste generations, reduce energy consumption among other things. These programs have concepts in common that can improve business results, those common factors are of management systems, waste identification and waste reducing techniques (WRT). When a company applies Lean practise, the by-product can be a reduction of environmental waste, even though the reduction is not the focus of the company objectives (Bergmiller & Mccright 2009). The elimination of re-work in lean practice is dependent upon designing systems that reduce generation of by-products, which in itself is environmental friendly (Mollenkopf et al. 2010).

There is strong evidence that minimized inventory and quality standards are correlated with lower emissions of toxic chemicals and pollution prevention (King & Lenox 2001). The reduction of waste is a result of process efficiency and quality improvements. Green and Lean systems have a similar structure and there is a synergistic relationship between these two practices. (Bergmiller & Mccright 2009a; Mollenkopf et al. 2010). Companies that are invested in a Lean structure have an advantage when it is of interest to pursue a Green way of running the business, and the other way around (Bergmiller & Mccright 2009). A company that already applying ISO9001, is also more likely to implement ISO14001. This could though be explained by adaptation of one standard makes it easier to implement one that is similar, rather than the experience with lean leads automatically to adaptations of environmental management standards (King & Lenox 2001). Environmental practice is argued to get better results and is the main force behind environmental performance, lean and supply management have on the other hand little to no connection with environmental performance. This entails that reduction of pollutants and energy consumption is a direct effect of environmental management, which is showed by comparing environmental management, lean management and environmental performance simultaneously (Hajmohammad et al. 2013). Another constraint between the practices is of how the environment can be view. In Lean practise the environment is a valuable resource, that differs in Green practice where the design and production of products are constrained from an environmental point of view (Dües et al. 2013).

3.2 Lean and Green Manufacturing

Lean production increases the employee responsibility and involvement in the waste reduction efforts. The involvement of employees is also important when adopting environmental practices, thus the pre-existing lean practise can be helpful to firms that aim for reducing its wastes and pollutants (Yang et al. 2011). By reducing pollutants the company can reduce cost of material use or by avoiding cost of waste management, thereby the activities of reducing pollutants are value added from a lean practice point of view (Simpson & Power 2005). Lean practice is not always correlated to reduction of pollutants. When lean plants were compared to other plants regarding environmental performance, it was found that lean plants had higher levels of volatile organic compounds emissions because of the painting process which was by spray paints. Although the method is cost effective and the end product is of higher quality, the environmental consequences are damaging (Mollenkopf et al. 2010). Companies that have just-in-time (JIT) manufacturing strategies also have better results relating to costs, and quality as well as other manufacturing performances. This derives from reductions of set-up time which leads to more efficient use of resources per produced unit. The effect is fewer defects and thus lower waste generation, that is better environmental performance (MacKelprang & Nair 2010).

Kurdve and Wiktorsson (2013) writes of the results of using a Green Performance Map (GPM) to study operational key performance indicators (KPI), compared with two companies environmental control and focus on a link between KPI and environmental sustainability. The authors note that the method of GPM is to create a visual tool to aid teams in identifying, prioritise, measure and follow up on activities that fall under environmental aspects. The method provides an overview on different aspects of the operation for the team and provides the necessary understanding. GPM consists of inputs energy, product material, process material and water and outputs; product output, non-product output, emissions to air and emissions to water and soil. To combine GPM with KPI each aspect in GPM is put into the map and then linked to measures from the KPI. The study of two manufacturing companies resulted in two identified applications of the GPM, from a management point of view the method provides an at-a-glance tool for the operations environmental sustainability. The authors suggest that the main processes data can be easily overviewed regarding their environmental impact and follow up on important measurements. The gathered data can be used as a tool to support decisions regarding sustainability. From the operator's perspective, necessary understanding of the importance of their day-to-day work regarding sustainability and environmental impact is created.

Another useful tool for lean and green manufacturing and production systems is an environmental value stream mapping (VSM). This approach combines the tools commonly used in lean manufacturing and environmental management. The latter can be measured by collecting data for energy used and material inputs/outputs throughout the processes of the studied area, a common method is Life Circle Assessment (LCA). A template can be created for data collection which makes it possible to collect data according to both VSM as well as environmental data. Some data can be used in both VSM and in calculating energy use by equipment. An

environmental loss model can be created for input regarding resource losses, here the environmental losses are derived from breaking down the full environmental impact cost of a process or activity. The model is a helpful tool for comparison of production performance and identifying environmental bottlenecks. The study showed that lean together with environmental VSM can decrease cost and environmental resources (Kurdve et al. 2011).

Using a computer simulation regarding lean and green strategies, the overall savings in production cost can be 10,8 percent as showed by a simulation done by Diaz-Elsayed et al. (2013). The simulation was tailored to a specific case study with specific combinations of strategies. The strategy that had the most effect in reduction of resource consumption and improvement of the organization of the manufacturing system was lowering batch sizes as well as integration of specific processes.

3.3 A Green and Lean Supply Chain

Companies are being pressured to have more environmental conscious supply chains. Among the sources of the pressure are the stakeholders which cannot be ignored, instead companies must integrate environmental management into its processes and corporate strategies (Mollenkopf et al. 2010). A traditional definition of a Supply Chain can consist of raw material, manufacturing, distribution, the retailer and usage of the product. The important entities in this Supply Chain are the manufacturer and its suppliers, vendors and, customers. With concern to a lean and green supply chain, an enhanced supply chain can consist with added activities, more specific; re-use and recycling throughout the life cycle of products and services. This includes dismantling and decomposition. For evaluation and measurement, the following metrics are used; supply chain return on asset, customer satisfaction and Life Cycle Assessment (LCA) (Kainuma & Tawara 2006). When the product is at the mature and the declining stage the suitable way of achieving a greener supply chain is to improve the existing processes by elimination of waste (Sarkis 2003). The customer satisfaction is measured with out of-stock ratio and return on asset is measured with average stock through a supply chain. The expansion of the supply chain is verified by computer simulation where different levels of information sharing are tested, the most efficient way is to share demand information as well as the supplier leadtime. The study points out the importance of collaboration between the entities within the supply chain. The outcome of sharing information reduces the bullwhip effect where there is a distortion of sales and the variance in orders, where the latter is greater than the former, which creates an upstream unbalance between a larger variance at the manufacturer or the supplier than the demand from the retailer. The shared information contributes to achieve and maintain a specific level of out-of-stock ratio and decrees inventories in supply chains (Kainuma & Tawara 2006).

Another approach for a model is given by Sheu et al. (2005) which point out the lack of a comprehensive framework that systematically manages logistic flow among the supply chain members. The root of the problem is considered to be different operational goals that maximizing profit at one member in the reverse logistics chain but increase cost at the manufacturer. Sarkis (2003) describes reverse logistics as the returning of the products to the company, where the products are recycled or reused and in that way, bringing the material back to forward logistics. The proposed model

by Sheu et al. (2005) is with integrated logistics operations and stands out due to its generally applications instead of being bound to a specific industry. Furthermore, the model takes into consideration government regulation which affects the manufacturer, such as fees for recycling. The model coordinates the cross-functional product logistic flow as well as the used-product reverse logistic flow in a green supply chain by identifying critical activities and related operational requirements. The result of the study is that profits can be improved by 21 percent in the selected supply chain, but most importantly that profits are more evenly distributed throughout the green supply chain.

A company's relationship with its suppliers are often focused on cost, quality and delivery, the environmental impact of the relationship is often disregarded in comparison with the three needs. If the environmental aspect is introduced in the basic needs of a supplier, and incorporate the aspect into the supplier performance specification, then the company is more likely to be able to protect its reputation and investments. This is due to the fact that the company can be able to meet the managements social responsibility targets and thereby improve the processes and opportunities for innovation. Practicing lean manufacturing is an indication of highly involved supply relationship, the relationship is also well structured and highly developed. The relationship can mutually lead to environmental management improvements with cost effective solutions when better understanding is reached regarding the supplier's business and especially the impact of environmental activities. The supplier relationship is important from both the supplier and buyer perspective regarding the implementation of environmental performance technology. Best result is achieved when both parties spend time at respective work place (Simpson & Power 2005).

Combining lean and green practice in the supply chain is derived from some major factors, these are of cost reduction, international standards, risk management and demand from customer. Risk management can be of Six sigma in the lean and green supply chain and concerns control variability and commodity risk management. There are many forces behind a making the step towards a more green and lean supply chain, unexpected enough competition does not belong to the major ones. On the other hand, profitability is strongly focused on. Green aspects differs from lean by capitalizing on the new markets and market segments that open up and thus potential profit sources (Mollenkopf et al. 2010). Environmental benefits from lean practice are not capitalized properly by companies, instead of strategically focus on the benefits, companies focus lay upon cost efficiency (Larson & Greenwood 2004).

3.3.1 Managing a Green and Lean Supply Chain

When working toward a more sustainable supply chain the manager and the company can be faced with different decisions, from choosing collaboration partners to how the product life cycle can influence the organizational strategies to become more green. The value chain of an organisation can influence the direction of the company by making greener purchasing decisions, which can be recyclable, reusable or already recycled materials. Another operational characteristic affecting green supply chain, besides from purchasing, is networks of distribution and transportation. This concerns mode of transportation, control systems, and just-in-

time policies and can influence forward as well as reversed logistics. The latter is as important as the forward logistics regarding sustainability from an environmental perspective. Material usage can also be reduced by efficiencies in packaging which directly affect the environment, not only will that reduce direct cost but also increase space utilization and reduce handling time (Sarkis 2003). Companies that have JIT delivery strategies can have a negative effect on green strategies. This is related to smaller lot sizes with that increase transportation frequency, but also due to packaging and handing of the goods. Companies in this situation must realize the negative consequence of JIT strategies and work toward green strategies by optimizing the utilization of transportation cubes and reusable packages and containers, just to name a few solutions (Mollenkopf et al. 2010).

The decision framework can be evaluated by performance requirements which can be those of cost, quality, time and flexibility. Although this factors are commonly used, and not specifically environmentally based, but can be useful when comparing performance from different alternatives regarding the green supply chain. An Analytical Network Hierarchy (ANH) is presented, the model is constructed of levels of decisions related to the products life cycle and different processes in the company that are influenced by company's goals and objectives to make the supply chain green. One organizations goals and decisions will affect the rest of the supply chain and will demand that the manager is analysing the independencies between the different organization within that supply chain (Sarkis 2003). One major barrier to implementation of green strategies in supply chain management is the lack of sufficient metrics, also the lack of managements awareness about the benefits of the strategies. There can be disbeliefs among managers that lean and green supply chains are effective, instead there can be concerns regarding the cost of implementation and that it is time consuming (Mollenkopf et al. 2010).

4 Analysis

In this literature study Lean and Green practices were compared in different aspects, main focus was upon manufacturing and supply chain, the later contained also aspects on management.

Lean and Green programs are strongly correlated as observed from the studied research articles. It is also noted that companies that already are applying lean production have an advantage when introducing green practices such as ISO14001. A common explanation as seen through the research is that lean practice is striving to reduce waste, it is one of the core objectives. Lean results are also enhanced by green practice, they are beneficial for each other. Another factor that is apparent in the literature was that lean activities contribute to environmental performance. Waste reduction was overall a major correlation between the two practices, in lean it was identified as a measurement of efficiency, where in green practice waste generation is an objective in itself. Elimination of re-work was one of the named activities, another activity was the minimalization of inventory and quality standards. It was apparent that Lean practice is an advantage when a company is pursuing greener results.

Lean manufacturing involves employees, the involvement of employees is showed as important when adopting also environmental practises. In manufacturing aspects, the reduction of pollutants and waste is value added as the reduction can also reduce costs in material use and waste management. Green performance map and environmental VSM was respectively valuable tools to achieve greener results. The former displayed the operations environmental sustainability as an at-a-glance tool for management, which can be used to support decision making. The latter can instead be used for comparison between processes and identifying environmental bottlenecks.

There is some different point of focus regarding a lean and green supply chain throughout the scientific literature. There can be added activities in the supply chain, such as re-use and recycling of the product throughout its life cycle. Different approaches are more or less suitable depending on which stage of its lifecycle the product is in. Collaboration in the supply chain is another approach, here information sharing of demand and lead time can reduce the bullwhip effect. Reverse logistics is utilized to bring used material forward in the logistics chain, by identify critical activities and related operational requirements, the overall profits can be improved with up to 21 percent. The supplier relationship in lean manufacturing is highly developed. A correlation is identified where the relationship can lead to environmental management improvements, especially when both parties spend time at each other's workplace. From the management perspective, some improvements to make the lean supply chain more green can be initiated, such as efficiencies in packaging or in material usage. Although different barriers for taking this step is also identified. Lack of sufficient metrics and awareness in the management can create disbeliefs.

5 Discussion

There is a consistency throughout examined research regarding the advantages from applying green and lean practice, especially when they are applied simultaneously. One major distinction was in the JIT part of lean. On the one hand, the manufacturing aspect of lean and green, JIT was found as a positive benefit for environmental performance due to reductions of set-up time. On the other hand, JIT delivery had negative consequences on green strategies, because of increased amount of transports. The conclusion is that JIT regarding manufacturing and delivery strategies have different results in comparison to environmental performance.

There is a common belief in the literature that lean and green practice are correlated and provide the company with better results regarding environmental performance, although there are some doubts as well. One of the scientific papers (Hajmohammad et al. 2013) have found that there is no substantial evidence that lean and supply management is connected with environmental performance. This can be argued as one source against years of previous research that say otherwise but provides a valid doubt in the practice. Furthermore, the authors have compared lean practice with environmental practice and found that the later achieve better environmental performance, which can explain their conclusion. In lean manufacturing the green performance is not always guaranteed. The use of spray paints in lean manufacturing

have a higher amount of volatile organic compounds emissions compared with non-lean manufacturing plants.

Regarding the lean and green supply chain the research focus is extended and results differs depending on the research area, such as the products life cycle, reverse logistics or the supplier relationship. The literature has been spread throughout different areas in the supply chain. One surprising finding was that there is no indication that competition is a contribution factor that forces businesses to take a step from lean supply chain to incorporation of green practice. Profitability is on the other hand one of the forces, not entirely unexpected.

Literature that was reviewed provided different aspects to this study, in retrospect the area of study could have been more narrow. The reviewed area was broadened by comparing Lean and Green practice in both manufacturing and supply chain, for a more in depth approach, one of the two areas could have resulted in a more focused literature review. Although, this approach can provide a more comprehensive overlook, thus possibly be a pre-study for future literature reviews. The review consists of 15 scientific sources, for more reliable result for future studies, more sources should be used to achieve a higher level of trustworthiness. Also, more recent scientific sources could be incorporated, as some of the literature could be considered as dated, even though it is merely a decade old.

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