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A Proposed Implementation Process for a Sustainable Manufacturing Framework

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Abstract. Trends in modern business management are increasingly pointing toward environmental practices that aim to reduce the impact on the environment and to achieve sustainability. Research in this area has sought to improve the tools and techniques traditionally used to improve operational performance to additionally consider the environmental impact of manufacturing. Green Lean, Environmental Management Systems and Life Cycle Assessment are examples of what manufacturing businesses are using to address the issue. However, a research project conducted by the authors has found that it requires more than just tools and techniques to transform traditional manufacturing into sustainable manufacturing, and a strategic approach is required to align the efforts of environmental and production management. To this end, a framework to integrate life cycle assessment and Lean Six Sigma is proposed. This framework has been developed based on data from questionnaires and interviews in UK manufacturing industry. The aim of this paper is to provide a description of how this framework can be implemented.

Keywords. Sustainability, Lean Six Sigma, Life Cycle Assessment, Framework.

1. Introduction

The need to achieve sustainability in industrial activities has been recognised due to several factors that continue to increase in importance. These include diminishing resources, customer demand for environmentally friendly products, and stricter environmental regulation [1-3]. Manufacturers have developed various techniques to manage these factors. Lean Six Sigma (LSS) is at the forefront of techniques to reduce the wastage of resources and focus on customer demand [4]. However, a shortcoming of LSS is that it is often applied with a focus on internal operations at the manufacturing stage without considering the impact on the other life-cycle stages of extraction, use and disposal. To consider these other stages, the use of life-cycle assessment (LCA) is crucial. Although LSS and LCA have been successfully implemented, the integration of the two techniques has not been extensively researched. Therefore, a research project was initiated to study the integration of LSS and LCA. It was found that the main goal of integration should be to satisfy environmental market requirements, and that the integration needs to be controlled by a strategy [5].

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2. The Framework

The framework has been developed in a research study on sustainable manufacturing. It captures relevant concepts and theory from the literature and builds on them using data from a questionnaire survey and interviews conducted in manufacturing industry. The results aided in the design of a framework that enables manufacturers to be sustainable by achieving a strategic fit across the activities of LSS and LCA as shown in Figure 1. Although the framework is expected to bring both tangible and intangible benefits when implemented, the main concern of manufacturers has been always the cost associated with new initiatives. Therefore, particular attention was paid to the cost of implementation using LSS, which is a popular technique and is very likely to already be used in the company. In addition, streamlined LCA was chosen as an alternative to full LCA to reduce time and costs [6]. The following sections discuss how the framework can be implemented.

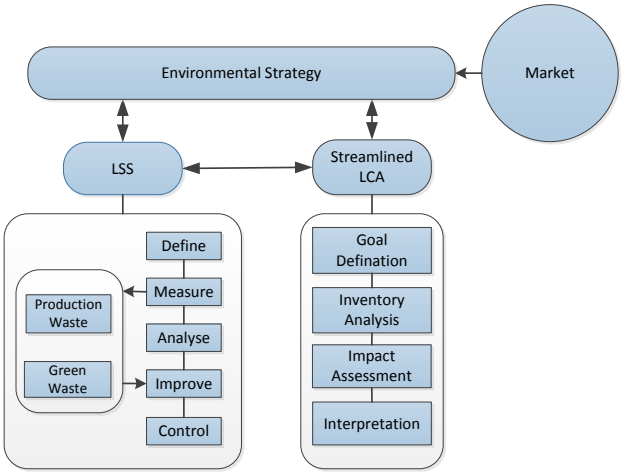

Figure 1: Framework to integrate LSS and LCA in an environmental strategy to deliver market requirements

3. Framework Implementation

The framework was designed for the purpose of linking LSS and LCA, as there is no existing research in this direction. Furthermore, empirical evidence has shown that linking the two techniques in practice is not common. This research focused on those responsible for executing LSS (the quality or production department), and found that, even in companies where LSS and LCA are implemented, LSS practitioners often do not participate in LCA studies, and the results of these studies are not directly communicated with them. The role of the framework is to provide an approach which would solve this problem. This paper presents a proposed implementation process for the framework as shown in Figure 2. However, there are other possible ways to implement the framework, as the process may vary according to the company's resources and whether it has LSS, LCA, or both. The steps of the suggested implementation in Figure 2 are outlined next.

3.1. Start/environmental strategy

A company starts by formulating a provisional environmental strategy based on information from the market and production processes. The team responsible for formulating this strategy is cross-functional so as to ensure that all departments are involved in the programme. Market information includes an assessment of the requirements of a company's specific market and its position in that market. In addition to environmental considerations, the environmental strategy should consider all factors that affect its market. A PESTLE (political, economic, social, technological, legal, and environmental) analysis is conducted to consider all market factors [7] so that the environmental strategy is not isolated from the corporate strategy. Production information includes the capabilities of the production function. A SWOT (strength-weakness-opportunities-threats) analysis is performed to determine how the production functions can achieve market requirements, and how they can be modified if currently incapable of this. The environmental strategy then proceeds to collect information about the impacts of the company's products on all life cycle stages by conducting a streamlined LCA study as discussed in subsequent steps. Engaging wider staff should also be considered early on in this phase to gain support for sustainability through idea sharing and commitment [8].

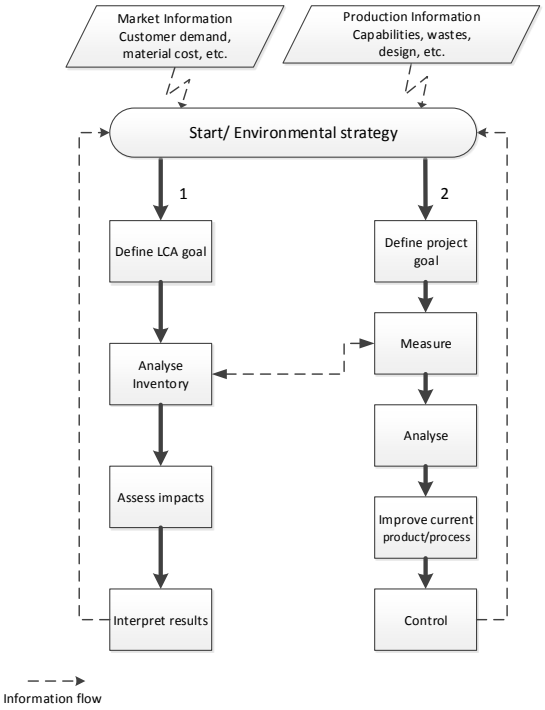

Figure2: Proposed process for implementing the framework.

3.2. LCA goal and scope definition

General guidelines for conducting an LCA are given in the ISO 14040 standards. In the first phase, the goal of the LCA study is determined based on information from the environmental strategy that defines the type of information needed to support decision making. For example, this can be information about water consumption in a market concerned about water supply, or information about gas emissions in a market concerned about pollution. An LCA study can have more than one goal. It can, for instance, seek to guide new product development to evaluate energy efficiency and CO2 emissions, and simultaneously prepare for product certification. The specificity of data should be determined at this phase to allow for a reliable streamlined study that is not as complicated and time consuming as a detailed LCA [9]. The scope of the study is also determined in this phase. The stages of the lifecycle are normally materials extraction, manufacturing, use, and disposal, and these are all typically included in the LCA study. However, a company might decide to limit the focus on some stages that it considers more important or has detailed environmental data about. The scope of the study defines the system boundaries, which are determined to include some of the lifecycle stages in detail and information is acquired about the other stages outside the system boundaries from environmental databases such as Ecoinvent.

3.3. Inventory analysis

The lifecycle inventory is quantified in this phase. This includes energy, raw material requirements, waste and emissions for the entire lifecycle of a product. Data about processes within the system's boundaries is collected. This data can be obtained from upgraded LSS tools that include environmental measures as shown by the information arrow in Figure 2. Depending on the scope of the study, the data in this phase is gathered for all stages of the lifecycle, or alternatively is obtained from existing datasets or other similar studies. Supply chain integration is important to facilitate data collection from companies in the supply chain. Data from the manufacturing stage can be obtained from meter readings from equipment, laboratory tests and equipment specifications. Data from the use and disposal stages can be obtained using customer surveys to find, for example, how many times the product is used and how it is disposed of.

3.4. Impact assessment and interpretation

The impact assessment phase of LCA categorises the large amount of data collected in the previous phase into impact categories such as land use, human health and global warming. Thus, it is possible to compare the different types of waste and emissions by comparing their impacts in different categories. The final task of LCA is to evaluate the results and relate them to the purpose of the study in the interpretation phase, which also checks the data in the previous phases to make adjustments to the study and produce a final report for the environmental strategy.

3.5. Amended environmental strategy

The environmental strategy can now be amended based on the information from the LCA study. The next step is to undertake an LSS project to evaluate the current state of the production functions and propose improvements to move to a future state.

3.6. Define

The goal of the define phase of the LSS's DMAIC process is to define the problem and the benefits expected in light of what the environmental strategy has provided. The cross-functional team is required to undertake the project with roles and responsibilities clearly outlined in this phase.

3.7. Measure

The current state is evaluated in this phase. A typical LSS would use tools such as Value Stream Mapping (VSM) and Just-In-Time (JIT) [10]. However, the framework requires tools that consider environmental impacts so that the measure stage can feed data into the inventory analysis of the LCA study. Tools such as Environmental Value Stream Mapping (EVSM) have been developed for this purpose [11, 12]. Other tools such as JIT can be altered to consider road congestion and CO2 emissions [13]. Upgrading the tools of the measurement phase to include environmental measures would stream information to the inventory analysis of LCA, which is beneficial for the company as time and resources are not wasted on doing the same task twice.

3.8. Analyse

This phase of the project analyses the data collected in the previous stage. Statistical analysis is performed to explore the problem in detail and identify variables that affect the process variation. Variables that are related to environmental performance would be considered alongside typical production variables. For example, a typical LSS would focus in its analysis on bottlenecks to improve throughput, but in the framework the environmental strategy sets guidance to also consider areas of significant environmental impact. Moreover, the typical cost-benefit analysis that estimates the benefits and costs of proposed improvements should be modified to include environmental impacts. The company's allocated budget for environmental improvements should be used to offset the costs of environmental improvements in the cost-benefit analysis.

3.9. Improve and control

The goal of these two phases is to implement improvements to the current state and activate control plans to document procedures and ensure that the improvements are sustainable. The documentation procedure to be adopted should follow the ISO14000 standards for environmental management systems. Karapetrovic and Willborn [14] suggest that an integrated system of ISO9000 and ISO14000 (EMS) is required to meet the requirements of both systems with less time, effort, and conflict.

The present study argues that LSS is important to support the implementation of LCA recommendations, and this support can be achieved by means of actions that ensure the LCA findings are addressed in the improve and control stages. Incorporating environmental education into LSS training programme is an example of how LSS can support LCA. Measures that statistically monitor the impact of the improvements in economic and environmental performances should be implemented in the control phase so as to constantly feed information to the environmental strategy. The process shown

in Figure 2 iterates in a continues cycle that improves the environmental strategy based on new information from the market, production department, LSS, and LCA.

4. Conclusion

The importance of environmental strategy is growing and there is a need for more research to explore it. To this end, this paper has presented a possible implementation process for a framework that integrates LSS and LCA to achieve environmental sustainability. There are other possible ways to implement the framework. For example, a company can start first with an LSS project to reduce resource consumption and prepare for further improvements using LCA. The implementation process includes the DMAIC cycle of LSS and the standard steps of LCA, and the importance of modifying LSS tools to include environmental measures stressed. So far, a literature review has shown that such tools are limited to VSM. Further research to modify other LSS tools such as JIT and statistical analysis will take place and is expected to provide additional improvements to the framework.

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