



**MÄLARDALEN UNIVERSITY
SWEDEN**

School of Innovation, Design and Engineering

Environmental KPIs for management and improvements in manufacturing

Increasing the employee sustainability commitment for Lean
and Green production at ABB

**(KPP231) Master Thesis Work,
30 credits, D-level**

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Abstract

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Degree Program: Product and Process development in production and logistics

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Course: Project in **Green production**

Title: Sustainable Development in Innovation, Design, and Technology Perspective.
Case Study of ABB Ludvika

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Problem Statement: How does ABB Ludvika facilitate sustainable development in technology, green production with green KPI's? The purpose of the thesis is to develop a general concept of environmental KPIs for management and improvement in manufacturing. Environmental KPIs can be a main driving factor for work improvement and they will be managed for the continuous improvement in company. The concentration is on the shop floor level including production management (on team levels and department levels). The capability of using different (standardized) KPIs for management and control and more flexible/dynamic KPIs on a local level for enhancing improvements on a daily basis should be investigated. This concept will be clarified to be understood by researchers and companies if they want to implement it. The aim of this thesis is to attain sustainability and to suggest possible gaps between the point of view of researchers and practitioners. The other objective is to find out the key factors involved in production processes that have significant effect on sustainable, and hence the environment.

Methods: Qualitative research methodology was used in this study. Two in-depth interviews were conducted with an Environmental manager and Production Manager, Purchase and Order Department, Quality Manager and Lean Process Department of ABB Ludvika with a focus on sustainable issues and technologies when the authors visited the manufacturing plant. Corresponding secondary resources from literature, articles, and theories were thus collected to be studied in parallel with the qualitative data.

Conclusion: The research found that ABB Ludvika has implemented a lot of business activities by applying technology and design approaches in order to support and improve its sustainable development business concept which covers all social, environment and economic aspects.

Keywords: Sustainable development, Sustainability, Green Production, Lean manufacturing, KPI's, ABB Environmental KPI's

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Introduction

This chapter illustrates the background and motivation for the research exhibits in the thesis. Further, aim of the project is stated, from which 3 research questions are derived, following the end of chapter short description of research context is described.

1.1 Background and motivation

Attention to sustainability is growing in today's industry. Green production is sometimes used to address production with a sustainable perspective and lean production has also been proposed as a source of attaining sustainability. Lean and green production systems require green usage of resources and efficient production.

In today's world, companies from various fields are dealing with environmental obligations. In the past few decades' un-preceded growth in population, economy, and industrialization cause massive use of natural resources to meet customer demands resulting in pollution of an environment and a decrease in natural resources. Since the last decade, corporate companies are getting interested in environmental protection and customers are demanding environment friendly products (Noah, V. and Bradley, W). Companies try to reduce their emission and resource utilization to prevent polluting the environment by managing their activities in their supply chain (Hart 1995; Corbett and Klassen 2006). The consequences of production waste on the climate were described in a report by the Intergovernmental Panel on Climate Change (IPCC) as:

“Warming of the climate system is unequivocal, as is now evident from observations of increase in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level” (IPCC, 2007a, p.5).

Since the impact on the environment of industrial and commercial activities has been more severe and vivid, people now challenge the belief that the environment can be treated as an endless source of resources and limitless depository for waste (Hoffman and Bazerman 2007). Key performance indicators (KPI) methodology and other similar techniques, like balanced scorecard, have been implemented mostly with business processes, but very little has been done in the area of production process management. Performance measurement is a fundamental principle of management. The measurement of performance is important because it identifies current performance gaps between current and desired performance and provides indication of progress towards closing the gaps. Carefully selected key performance indicators identify precisely where to take action to improve performance (Andrej and Vladimir, 2004). Even though green production technique is gaining popularity in manufacturing industries, most of the specialists in industry do not have actual knowledge of what is green production and its frameworks are, how to identify the best practices of a green production technique, what the environmental impacts of production technique & their Key Performance Indicators (KPIs) are.

1.2 Aim of the thesis

The purpose of the thesis is to develop a general concept of environmental KPIs for management and improvement in manufacturing. Environmental KPIs can be a main driving factor for work improvement and they will be managed for the continuous improvement in a company. The concentration is on the shop floor level including production management (on team levels and department levels). The capability of using different (standardized) KPIs for management and control and more flexible/dynamic KPIs on a local level for enhancing improvements on a daily basis should be investigated. This concept will be clarified to be understood by researchers and companies if they want to implement it. The aim of this thesis is to attain sustainability and to suggest possible gaps between the point of view of researchers and practitioners. The other objective is to find out the key factors involved in production processes that have significant effect on sustainable, and hence the environment.

1.3 Research Questions

A research question is a suggestion that identifies the phenomenon to be studied. In order to limit the scope of the study and avoid over elaboration, the research has focused mainly in answering the following three key research questions.

1. How can the use of KPI's contribute to a green production system?

KPIs have a special meaning to work place learning by considering organizational strategy, structure, and systems (e.g., job system and reward system). KPI bridges the gap between an organization's mission and vision and its employees' targets (Ran and Wang, 2008). We seek to find out the factors that influence or contribute to the green production system in an organization.

2. What are the barriers and drivers in the production process in attaining green manufacturing practices?

The second part explains different barriers and drivers for the company's green manufacturing practices. The sustainability is a crucial issue for present and future generation. Cost efficiency is not the only factor in attaining green practice but the impact of products and technique to surroundings and environmental footprints are other factors which ought to be keeping in account.

3. Why it is difficult to measure and practice Green in today's world?

The idea of attaining Green manufacturing is crucial in preserving our natural resources for present and future generations. It is thought as high cost, incalculable difficulties and requires full determination although; despite of all factors companies have taken initiatives for implementation of Green.

1.4 Research Context

The Master thesis has been a part of the research project “Green Production Systems” (GPS) (2009 –2012) funded by FFI/VINNOVA with Haldex, Saab, Volvo, All-Emballage as co-funding industrial partners and Mälardalen University as the academic partner. ABB has participated throughout the project by supporting with their environmental expertise. The objective of the GPS-project has been to reduce the environmental impact of the production system, especially in operation, and to facilitate the environmental improvement work by integrating it into the existing infrastructure for improvements that is achieved through the industrial implementation of Lean Production. The objectives of the GPS project have been:-

- 1) To set the preconditions and frames of what a GPS is.
- 2) To identify the best practices of green production systems.
- 3) To visualize the environmental impact and added value of a production system.
- 4) To find ways of following-up and managing a GPS.
- 5) To develop guidelines for value improvement and cost decrease by environmental strategies and actions within and directed towards the production system.

Thesis contribution

In this research, the researchers aim to identify and analyze how ABB Ludvika improves sustainable development, KPI's and E-KPI's. ABB Ludvika is chosen as the subject of the study since it is the one of the leading company that has efficient implementing system of technology design that truly solves the environmental problem that their business can cause. In addition, organizational aspects of sustainability and Lean and Green manufacturing are discussed after examining ABB Ludvika case by focusing especially to how it helps the firm achieve to have sustainability development.

Research Methodology

The chapter illustrates the research methods in general and discuss particular reasons for choosing the research method and how the data collection techniques, interviews, analyses and evaluations of the findings compliment the research conclusions.

2.1. Research approach

There are different possible approaches to a research design. These are qualitative, quantitative and mixed approach. It is necessary to make a choice from the three approaches listed above in order to have a well-structured research design and hence outcome. In order to do that, perhaps the first step is to learn what constitutes each method. Creswell (2006, pp. 3) suggests three framework elements of each approach to consider while learning qualitative, quantitative or mixed approach. These are; philosophical assumptions about what constitutes *knowledge claims*, general strategy of research called *strategies of inquiry*, and detailed procedure of data collection, analysis and writing called *methods*. After assessing these elements of framework, the research approach is selected. Bryman et al. (2007, pp 28) described the basic characteristics of qualitative and quantitative research approaches as follows:

“Quantitative research can be constructed as a research strategy that emphasizes quantification in the collection and analysis of data and that entails a deductive approach to the relationship between theory and research, in which the accent is placed on the testing of theories.”

“Qualitative research can be constructed as a research strategy that usually emphasizes words rather than quantification in the collection and analysis of data and that predominantly emphasizes an inductive approach to the relationship between theory and research in which the emphasis is placed on the generation of theories.”

This thesis is mainly about exploring, conceptualizing KPIs, Lean and Green theories. The expected result of the thesis is more inclined to be expressed in a qualitative manner than quantitatively. For this reason a qualitative research approach is used in this thesis. Table:1 shows generic steps taken in selecting the research approach and design.

Table 1: Choosing research approach and design process, Creswell (2006)

Approaches to Research (step 1)	Design process of research (step 2)
<p style="text-align: center;">Quantitative Qualitative Mixed Methods</p> <p style="text-align: center;">(Approach selected)</p>	<p style="text-align: center;">Research purpose Research Questions Theoretical frame work Data collection and Analysis Write-up</p> <p style="text-align: center;">(Design according to the selected approach)</p>

It should be noted, however, that the difference between qualitative and quantitative research approaches is not always strict. This is to mean that, though a research can be predominantly approached in either of the two methods but it can also contain some characteristics of the other. This is also supported by Bryman et al., (2007, pp. 29) as “*However the distinction (between qualitative and quantitative research approaches) is not a hard- and- fast one: studies that have the broad characteristics of one research strategy may have a characteristic of the other*”. After the selection of the research approach (qualitative), the design of the research components is made. These are the purpose, research questions, theoretical frame work, and data collection as presented below.

2.2 Data Collection Method

According to Kumar (2005), there are two different types of data collection for analyzing and replying the research questions called primary and secondary sources. Below flow illustrates method of data collection.

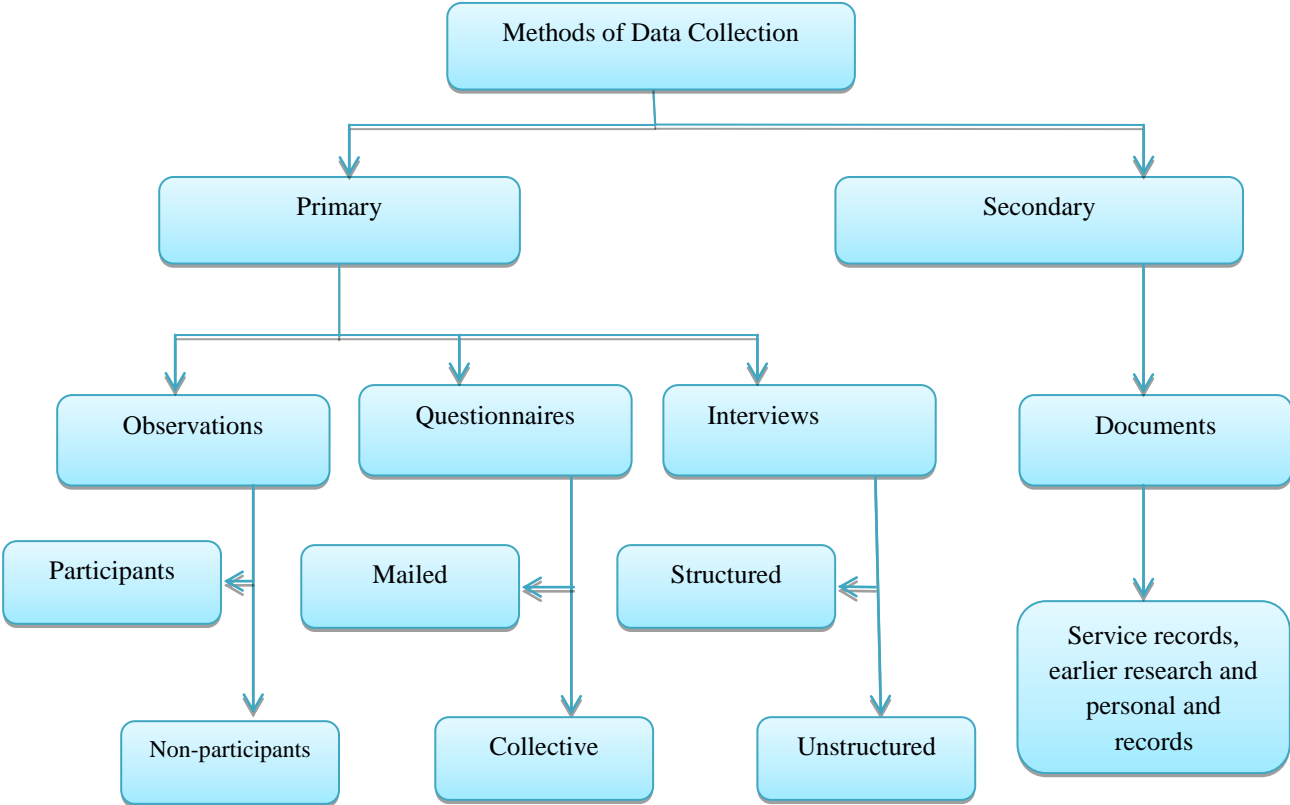


Fig 1: Data Collection Method (Kumar (2005))

Both sources primary and secondary of data collection methods are used in this research in order to gain the objective and answer the research question. Information collected using the first approach is secondary sources, whereas the sources used in the second approach are called the primary sources. Data gathered from empirical studies is qualitative data. Saunders, Lewis and Thornhill (2007) observed that qualitative data is more likely to provide such a richness of information than quantitative data. This is a vital reason for researchers to emphasis on qualitative in order to attain the objective of research.

2.3 Research Design

The research design explains the process how research is done. The steps are rendering in figure 2

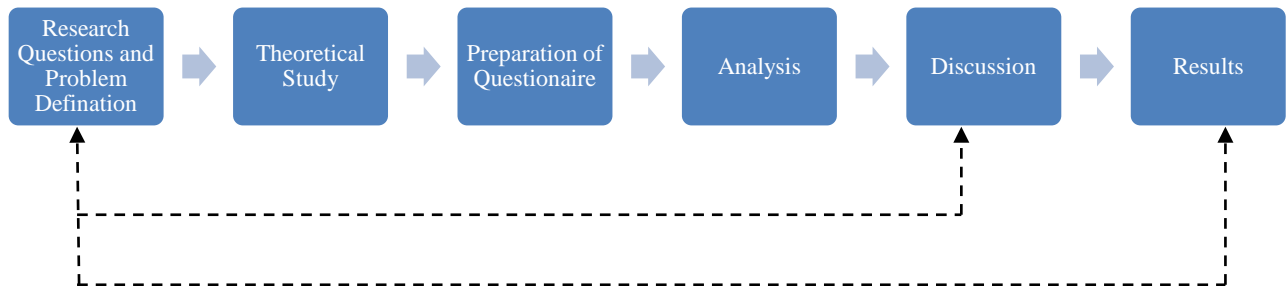


Fig 2: Research Design by Author

The thesis was performed under the supervision of the thesis supervisor. Most of the conversation and communications were done through e-mail and meeting in personal. The qualitative research was evaluated and the researcher, research design followed is presented in the above figure.

Literature review

A literature review is an analysis of the research work done in a specific domain. According to Hart (1998) defines literature review as, *“the selection of available documents on the topic, which contains information, ideas, data and evidence. This selection is written from a particular standpoint to fulfill certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research is being proposed”*(Hart 1998).

Purpose The main aim of the literature review is to certify the research ability to conceptualize the related information for the scope of work, construct a validating theoretical framework for the subject, defining keywords, definitions and terminologies, determining preceding research works in order to justify the research topic.

Writing a review The writing begins with identifying the research questions followed by examining and locating the needed information. According to Hart (1998) the first step should be writing a draft considering the expectation and the needs of the readers. Next step is reworking the draft, considering about clarity and structure of the paper until obtaining a final draft. Finally, check the grammar and spelling, the literature review is done.

A deep study has been performed with in the research area of lean, green manufacturing system, and key performance indicators by reviewing through related literature. The understanding in green manufacturing system and environmental KPI's contributes to the establishment of theory of KPI's.

2.3.1 Interview Preparations

The questions were designed according to the type of represented to be interviewed. The question forms are prepared according to the context of sustainability, lean, green and KPI's. The purpose of the questions prepared is to know how the ABB plant in Ludvika is working with the above mentioned areas, and to bring awareness about the lean, green and KPI's.

2.3.2 Preparing the questionnaire

The questionnaires were formulated in accordance to the objective of the thesis. In order to make the interview sessions easy and understandable, the questions were formulated with the relevancy of the research questions. The questionnaires were given with multiple choice questions and the representatives were also provided the options to give their suggestions.

2.3.3 Interviews and Participants

The interview method is the most common method in qualitative research. Interviews were conducted at ABB Ludvika after a brief visit of the plant and its process. Participants were selected from different departments in order to get brief response of company professionals. The list of participants is presented below.

List of Participants:

- Environmental Manager: Hågan Hultgren
- Quality Manager: Bengt Darlgren
- Production Manager: Tomas Eriksson
- Purchase: Conny Pers
- Order Department: Niklas Tegner
- Lean Process Department

In order to get significant replies the interviewers usually has some flexibility to ask further questions. Interview sessions were depended on the time slots given by the company professionals and vary to different persons. In order to get some missing information correspondence were done through e-mail.

2.4 Validity

Validity brings up to the limits to which researchers are able to use their method to study what they had sought to study rather than studying something else (Bryman, 2001). Validity can be divided in two types: internal and external. Internal validity refers to whether the conducted studies really represent causal relationships in the cases where they exist. External validity is related with the width of the results and whether it is probable that the results can be applied in other situations or at other occurrences than the ones actually studied (Gummesson, 2000).

2.5 Reliability

Reliability is referred to the reproducibility of the research and the extent to which two or more researchers studying the same phenomenon with similar purposes could reach approximately the same results (Gummesson, 2000). It is more relying on the researchers own interpretations. Thorough attention to how data and information is collected, analyzed and interpreted can strengthen the reliability aspect (Bryman, 2001).

Summary of Research Methodology

To summarize the research methodology, a research method has been illustrated and discusses for selecting the research method. A research approach was chosen to create a research design, which explains how research is done. Data collection method was followed for analyzing and replying research questions through primary (theory) and secondary (interview) sources. Data collection compares empirical results of ABB plant in Ludvika's performance with the findings in the literature study. Analysis and discussion has to be done to achieve result.

3. Theoretical Framework

3.1 Sustainability

Sustainability has not been a fashionable idea from now on, since it has been widely embraced by governments and organizations over the past 20 years. Its meaning and implications have been controversial; however it was still widespread (Gibson, 2005). The definition of sustainability that's most generally referred is from the global organization Brundtland Commission, who defined sustainability as

“Meeting the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987)

Traditionally, environment has been a primary concern in sustainability concept (Newport, Chenes, and Lindner, 2003). When individuals talk about sustainability measures, plenty of stress is added onto environment while the other two dimensions go unnoticed a little bit. In fact, sustainability has three aspects. Besides environmental sustainability, economic sustainability (economic development) and social sustainability (social equity) is the two other sustainability implications (Elkington, 1997). The three components of sustainability are (Commonwealth Association of Architects, 2003):

1. *Environmental sustainability* needs natural capital that is still intact. This shows that the supply and sink functions of the sustainability mustn't be degraded. Therefore, the extraction of renewable resources mustn't exceed the rate of renewal, and also the absorptive capability to the environment to assimilate wastes mustn't be exceeded. Additionally, the extraction of non-renewable resources ought to be decreased and may not exceed in agreed minimum strategic levels.
2. *Social sustainability* requires that the cohesion of society and its ability to figuring out towards common goals be maintained. Individual desires, like those for health and well-being, nutrition, shelter, education and cultural expression ought to be met.
3. *Economic sustainability* happens when development that moves towards social and environmental property is financially possible.

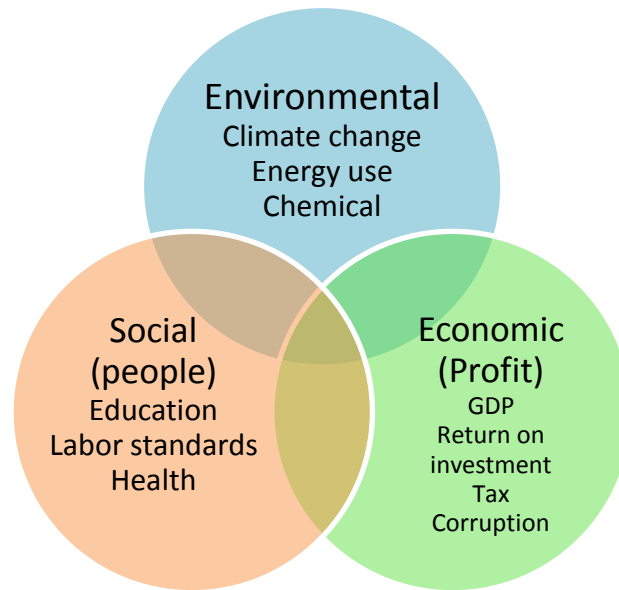


Fig 3: Chart of Three dimensions of sustainability (Elkington, 1997).

However, when the idea of sustainability applies into business activities, particularly in industrial sectors, companies have to maintain balance between their profits, employees, and internally and externally environmental cares. The profit and the human workforce have been the traditional key of success and main concepts once conducting policy, strategic and sensible implementation, and all kinds of business manner.

3.2 Definition of Lean

Lean can be described as a philosophical thinking which primarily focuses on eliminating waste. In Japanese *muda* means “waste” and as described by Womack and Jones (2003) it represents any human activity that utilizes resources but creates no value. Lean thinking is a power tool to counter *muda*. Womack and Jones (2003) described lean thinking as a path to do more work with less human efforts, equipment, time and space according to what customers really requires. Lean thinking provides a pattern for satisfied work allowing immediate feedback on efforts to convert *muda* into value. “The Toyota Way” (Liker, 2003) describes eight types of wastes according to Toyota which includes,

Over Production – Production of more items than ordered by the customer.

Waiting – Waiting time for operators for a reason than lack of order.

Unnecessary Transport – Unnecessary or excessive transportation of raw material or products from one place or station to another.

Over Processing – Performing non-value added or extra processing step in process.

Excess Inventory – Extra raw material, WIP (work in progress) or finished products increases storage costs and longer transportation.

Unnecessary Movement- Non-value added motion of parts or employees during processing or work e.g. walking, looking for, reaching for, stalking parts etc.

Defects – Production of defective parts or rework.

Unused Employee Creativity – This refers to losing ideas, skills, improvements and opportunities from employee experiences.



Fig 4: Types of Waste (Liker 2003)

3.2.1 Principles of LEAN production

Five principles could be identified as the fundament of lean production (Womack & Jones 1996). The principles can be summarized as the following:

1. Specifying value from the customer's point of view. It is critical to know who the customers are and what the customers wants to buy. Customers buy the end results, not the product itself. For example, they want to buy fresh meat but not a refrigerator. This intends to means they buy the refrigerator to keep the meat fresh, but not the refrigerator itself, since it doesn't make sense if the refrigerator does not have the function which meets the customers' requirement.
2. Identifying value stream. It is evidential to realize the sequence of processes all the way from raw material to final customer, or from product concept to market launch. As discussed in first principle, from customers view point, value equals to anything that the customers is willing to pay for in a desired product or service. Thereby the tool VSM-

value streaming mapping (VSM) is developed in order to analyze or map the process for determination of value-added and non-value added work.

3. Flow. Value-creating steps should be developed in clinched sequence so the product will flow smoothly toward the customer. One-piece flow is developed to make value flow.
4. Pull. Value is pulled by the customers from the next upstream activity as the flow is introduced in the system.
5. Perfection. Perfection refers to the perfect value. As value is elaborated, value streams are identified, non-value steps are removed, and flow and pull are introduced, begin the process again and continue it until a state of perfection is achieved in which perfect value is created with no waste.

From the above discussion we can say that Lean is a mindset, or way of thinking, with a dedication to accomplish a waste-free operation that is focused on customer's needs. It is achieved by simplifying and continuously improving all processes and relationships in surroundings of trust, respect and full worker involvement. It is about people, simplicity, flow, visibility, partnerships and true value as perceived by the customer.

3.2.2 Lean Tools and Methods

Lean has a wide variety of tools and methods which assist in developing an efficient production system. In this section selected tools and methods which are utilized by the case company are presented.

5S

5S can be defined as a system to reduce waste and optimize productivity through workplace organization and standardization carried out systematically. The main aim of 5S is to create an efficient, clean and well organized working environment. 5S always strives to improve operators and workplace safety, quality and throughput. 5S can be specifically described as (Liker, 2004);

Sort (Seiri) – focuses on removing or eliminating all unnecessary items from the work area that are not needed for current production system.

Set in Order (Selton) – focuses on efficient and effective methods to arrange needed items in order to find, use and return reducing searching time for them.

Shine (Seiso) – focuses on cleaning workplace and equipment. This results in creating a safer work place and quick identification of problems.

Standardize (Seiketsu) – focuses on creating a standardized approach for carrying out tasks and procedures at the work area which can be maintained through visual control.

Sustain (Shitsuke) – focuses on sustaining by creating discipline and commitment for all stages of work.

Implementation of 5S results in reduce inventory, efficient utilization of workplace, reduction of time for spare parts or tools, increase discipline and following procedures, but 5S also create impacts on environmental issues related to production such as reduce air/ water / air leakage, improving machine conditions, reduce accidents.

Just in Time

Just in time is a term used in Lean manufacturing system indicating a process is resourceful enough to tackle the demand of without need for overstocking, whether in term of additional demand or inefficiencies taking place in process (Hutchins, 1999). In Lean manufacturing JIT works as continuous improvement in terms of organizations return on investment through shrinking inventory level, improving product quality, improving efficiency of process, reducing lead times and other costs.

Value Stream Mapping

Value stream mapping is a lean tool which is used in lean manufacturing to elaborate the flow of material and information, as a product it makes way through value stream. VSM is a method which is used to form a “single page picture” of all ongoing processes in company, starting from placement of customer order until delivery of the order to customer. The main goal of VSM is to decrease or eliminate non-value added work, in order to achieve lean manufacturing goals.

Womack and Jones (1996) conceive the value stream as follows: raw materials along with knowledge and information enter the system upstream (the suppliers); and, products or services of value flow out from the system downstream (the customers). The value stream map, developed at Toyota, is a tool that:

- Allows you to diagram your current value stream;
- Identifies the bottlenecks that prevent you from making what your customers want, when they want it;
- Develops a vision of what your future lean system should look like.

One-Piece Flow

One-piece flow or continuous flow processing is a concept which means that a single unit is processed and moved from one processing step to another at a time. On the contrary, batch production involves a large number of products processing at a single time and forwarding

them together as group through each operational step (LSS Academy, 2008). On the other hand one-piece flow primarily focuses on product, instead of waiting, transporting and storage of them. One piece flow works on pull system rather push and requires short changeover time.

SMED

SMED (Single Minute Exchange Die) is a method which is used to decrease changeover time dramatically at the constraint (Vorne Industries Inc., 1999). As many steps as possible are converted to external (perform when process is ongoing), while remaining steps are streamlined (e.g. bolts and manual adjustments are eliminated).

Impacts of SMED:

- Increases usable production time at the constraint.
- Enables smaller lot sizes, resulting in improved responsiveness to customer demand.
- Enables smoother start-ups, since a simplified and standardized changeover process improves quality and consistency.

Summary

LEAN production can be described as the 21st century production system, as compared to mass production which was the production system of 20th century. Mass production system concept is based on long production runs using standardized design, which ensures that the customer will get low cost product with less variety and workforce produce as much as possible regardless of product consumption. On the other hand, 'lean' follows small batch production based on customer requirements in terms of orders, quality and innovation, which results in efficient utilization of workforce, material and process. Implementation of lean in production process results in half manufacturing space, human effort, investment and engineering hours to develop a new product. Lean creates value in the process through JIT strategy and eliminating unwanted wastes in the process which affects the product cost, which customers do not want to pay.

The ability to eliminate waste throughout the process makes lean a good player to achieve environmental objectives of the organization. Professionals often overlook the opportunity to reduce or eliminate environmental wastes through Lean implementation. Organizations can improve their performance of Lean implementation by considering environmental impacts, so that environmental wastes can be identified explicitly during Lean activity (U.S.EPA, 2007).

Lean not only reduces environmental waste, but also helps prevent pollution by providing access to detailed process information, involving stakeholders in the process, and ensuring supports from top management (Vanderheyden et al., 2004). Lean focuses on overall performance rather than individual departments, seeing the organization as a whole. Environmental or green issues also come under the whole performance perspective.

Tice et al. (2005) discussed more similarities between Lean and environment issues that:

- They both aim to involve people in the entire organization, crossing the boundary of departments, at all levels;
- They both rely on a continuous improvement philosophy supported by performance measurement;
- They both seek to foster an organizational culture that encourage people to take the responsibility of solving problems and improve for better.

Apart from ability to solve environmental or green issues, Lean has weaknesses regarding to improve environmental performance. In the perspective of waste elimination, it focuses on the amount of waste, but does not concern whether there is an alternative solution of more environmental friendly or less hazardous materials. Also, Lean only intends to eliminate waste which occurs during production, but environment management cares about the full product life cycle impact. For example, waste could occur at disposal of product (Tice et al., 2005). In order to negate the short comings of lean regarding environmental issues, a new system with more emphasize on environmental performance has been developed called as “Green Manufacturing System”.

3.3 Green Manufacturing

3.3.1 Introduction to Green

In the past few decades’ un-preceded growth in population, economy, and industrialization causes massive use of natural resources to meet customer demands resulting in pollution of environment and decrease in natural resources. Since the last decade corporate companies are getting interested in environment protection and customers are demanding environment friendly products (Noah, V. and Bradley, W). Companies try to reduce their emission and resource utilization to prevent polluting environment through managing their activities in their supply chain (Hart, 1995; Corbett and Klassen, 2006). The consequences of production wastes on climate were described in a report by Intergovernmental Panel on Climate Change (IPCC) states that (IPCC, 2007a, p.5):

"Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes, and wind patterns."

3.3.2 Definition of Green Manufacturing

Green Manufacturing is commonly defined as “elimination of waste by re-defining existing production process or system” (Balan 2008). This concept does not limits to address only the social and environmental impact of pollution-centric process but also process redundancy, ergonomics and cost implications due to inefficient methods of producing goods. Traditional production measures *faster* and *cheaper* are no longer success measures for manufacturing a

product or evaluating an existing process line, but also other success factors such as materials used in manufacturing, generation of waste, effluents and their treatment method, life of the product and finally, treatment of the product after its useful life are important elements that are described by green manufacturing approach as success factors

The Center for Green Manufacturing at Alabama University defines green manufacturing in their mission statement as: “To prevent pollution and save energy through the discovery and development of new knowledge that reduces and/or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products or processes”.

Balan (2008) states that all problem solving approaches and innovative techniques towards effective environmental solutions that result in cost savings from reduced work handling, effluent control, and process automation or other environmental and operational benefits can be named as applications of green manufacturing.

The issues that green manufacturing is mostly addressing on a process level according to the objectives of green manufacturing can be stated as follows (Pal 2002),

- Provide a cleaner source of energy through new technology or approaches.
- Decrease energy consumption in processes by implementing new technology or approaches.
- Convert pollutants and wastes into byproducts and promote their use and recycling along with that of the product in order to reclaim the energy expended in the process and conserve resources.
- Maximize yield and minimize waste effluents via process improvements, such as by tailoring feedstock selection, selecting proper fuel mix, automation, and establishing control strategies via sensors with real-time feedback loops that control process parameters.

3.3.3 Green (Environmental) Wastes

Green (environmental) wastes can be defined as excessive use of resources utilized or released in air, water or land that harms the human health or environment. When organizations provide products or services to customers, or customers dispose of the products cause the creation of environmental wastes (EPA).

According to EPA (U.S. Environmental Protection Agency), environmental wastes does not create/add any type of value to customers whereas causes cost bearing to environment and society. Environmental wastes directly effects production costs, flow, time and quality of an organization. Environmental wastes can be seen as an indication of ineffective production.

Environmental wastes can be found in almost any process and typically includes,

- Energy, water, or raw materials consumed in excess of what is needed to meet customer needs.
- Pollutants and material wastes released into the environment, such as air emissions, wastewater discharges, hazardous wastes, and solid wastes (trash or discarded scrap).
- Hazardous substances that adversely affect human health or the environment during their use in production or their presence in products.

3.3.4 Key Elements of Green Manufacturing

1) Eco Audit

An Eco Audit can be defined as a management tool comprising a systematic, documented, periodic and objective evaluation of the performance of the organization, management system and processes designed to protect the environment with the aim of (1) facilitating management control of practices which may have impact on the environment, and (2) assessing compliance with company policies. (CEC, 1993). On a detailed level it can be explained as an integrated resource use analysis that identifies opportunities to reduce environmental impact, increase performance and save money.

According to Friend (2009), Eco Audit holds a broad area of resource use examinations which includes “climate control”, “lighting”, “motors and appliances”, “load management” and “Water” in facilities and equipment usage area. Most significantly, when processes are taken into consideration additional usage of examinations can be specified as “equipment use”, “waste and recycling” and “material”. Friend (2009) asserts that equipment usage has to be rightly operated, and an organization’s waste is defined through its purchases and he expresses the importance of manipulating or controlling of waste and recycling activities along with Environmental Preferable Purchasing in an organization. These essential process elements can be handled and greened by Eco Audit systematic assessments.

2) Carbon Foot printing

Carbon foot printing can be described as an indicator or tool to monitor greenhouse gases in manufacturing processes, carbon emission through transportation, energy efficiency and fossil fuels. “A carbon footprint is the measure of greenhouse gases (GHGs) produced by a given activity, product, business, or supply chain, expressed in tons of carbon dioxide equivalents (the standard unit for describing carbon dioxide emissions)”. Identifying and knowing corporation’s carbon footprint leads to (Anastas, P T. & Zimmerman 2003);

- Identification and prioritization of efficiency improvements regarding carbon usage
- Evaluation of GHG reduction scenarios and strategies
- Availability of organization’s carbon position
- Developing strategies for green process design, environmental impact management and having better carbon footprint position through reduction.

3) Design for the Environment (DfE)

Design for environment can be described as an innovative approach which manufacturing organizations utilize to make traditional business decisions along with environmental impacts considering the cost and performance. It is developed by Environmental Protection Agency (EPA, 2011) as a voluntary program which works directly with the organizations in order to adapt environmental and health considerations in their business decisions into design and resigning of products and processes.

DfE program enables organizations to design or redesign products, processes and management systems by making them cleaner, more cost-effective and safer for workers, public and environment. The main objective of DfE programs while working along with industries and organizations is to compare the human health and environmental risks, performance, and costs associated with existing and alternative technologies or processes (EPA, 2011).

EPA specifies the main elements of Design for the Environment program to achieve a successful green business design as following (EPA, 2011):

- Evaluation of the human health and environmental impacts of its processes and products
- Identification of what information is needed to make human health and environmental decisions
- Conducting an assessment of alternatives
- Considering cross-media impacts and the benefits of substituting chemicals
- Reduction of the use and release of toxic chemicals through the innovation of cleaner technologies that use safer chemicals
- Implementation of pollution prevention, energy efficiency, and other resource conservation measures
- Making products that can be reused, refurbished, remanufactured, or recycled
- Monitoring the environmental impacts and costs associated with each product or process
- Recognizing that although change can be rapid, in many cases a cycle of evaluation and continuous improvement is needed.

4) Environmental Management System (EMS)

An Environmental Management System (EMS) can be essentially described as a systematic approach to ensure the management of environmental activities in any organization. International Organization of Standardization (ISO) describes a more specific definition as “that part of the overall management system which includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy” (EPA, 2011).

EPA states that many organizations have gained economical improvements by improving efficiency and reducing environmental risks throughout their environmental processes. An EMS helps organizations to spot environmental issues that result in economical enhancements when handled, proactively and accommodates with rules. Organizations utilizes process

mapping in order to identify environmental impacts during operations; cost related environmental management can be monitored by cost accounting tools and decision making tools can be used to identify alternatives and solutions as a part of EMS (EPA, 2011).

Characteristics of a Basic EMS can be described as the following:

The EMS is focused on and driven by environmental impacts of an organization. It handles a core set of planning activities in order to provide:

- Identification of operations and process that impact the environment
- Evaluation of impacts that are significant
- Objectives and targets to reduce significant impacts
- Identification and implementation of activities to achieve identified targets

Integration of environmental management and business function is promoted by the EMS by integrating environmental management with other operations and overall management practices. Examples can include:

- Top management defined environmental policies
- The effect of operating conditions and controls on targeted environmental impact consideration
- Periodic management review of environmental performance and other results

Continual improvement is provided by the EMS through the following:

- EMS procedures to monitor compliance and correct or eliminate problems
- Monitoring and evaluation of activities related to targeted impacts
- Identification of needed improvements and periodic assess progress evaluation
- Specific authorities, timelines and designated responsibilities for executing the environmental performance and associated cost improvement plan.

Hillary (2004), states that there are two formal, mainly used EMSs in the industry that can be named as EMAS (The Eco-Management and Audit Scheme) and the International Environmental Management System standard ISO 14001 seek to provide all businesses with the means to develop systematic approaches to improve environmental performance.

According to U.S. Department of Energy and U.S. Environmental Protection Agency (EPA), an EMS can enable organizations to make a predictable structure for assessing, managing and continuous improvement of the efficiency and effectiveness of their environmental activities. Instead of a crises management, an EMS approach forms a periodic review of environmental activities with an emphasis on continuous improvement. Furthermore, an organization can focus on management implementation and take a more inclusive and proactive view of

environmental protection by the systematic nature of the EMS. More inclusive and proactive environmental protection and management implementation focus will lead to an improvement of environmental performance which enables organization to have improved relations with regulators, stakeholders and the public.

Potential benefits of implementing an EMS can be summarized as the following (Tice, J. & Ahouse, L. & Larson, T., 2005):

- Improved environmental performance
- Reduced risk of noncompliance with environmental laws and regulations
- Reduced operating costs
- Bolstered corporate image
- Improved internal communications
- Enhanced environmental decision making
- Reduced constraints on process improvement activities
- Identification and elimination of hidden environmental wastes and costs

International Institute for Environment and Development (IIED) states disadvantages of EMS as follows:

Developing and implementing an EMS may have some costs issues. Some organizations can face political and/or administrative barriers in effectively implementing the requirements and commitment of an EMS (particularly if a standard is being followed, such as ISO 14001). There may be a reluctance to make the necessary financial commitments. They may also lack adequate and appropriate knowledge and technologies.

One disadvantage of an EMS is that, by definition, system facilitates larger organizations; the larger the organization, the more likely it has already developed a similar systematic approach to management processes.

5) ISO 14000 Standards

According to International Organization of Standardization (2011), organizations are becoming increasingly aware of the need for environmental management, socially responsible behavior, and sustainable growth and development. Proactive management of environmental issues is being directly related to enterprise risk management, corporate governance, and sound operational and financial practices and performance. Therefore, International Standards (ISO 14000 series, International Organization of Standards for environmental management) are becoming more and more essential to organizations to achieve common and comparable environmental management practices to support the sustainability of their organizations, products and services.

Origins of ISO 14000 was established by ISO technical committee ISO/TC 207, environmental management, which is responsible for developing and maintaining ISO 14000 family of standards. As a result of ISO/TC 207 studies, the ISO 14000 family of standards for environmental management was released in order to assist organization sustainable

development implementation actions as a practical toolbox. ISO defines the scope of ISO/TC 207's, which addresses several areas of work as following (ISO, 2011),

- Environmental management systems
- Environmental auditing and related environmental investigations
- Environmental performance evaluation
- Environmental labeling
- Life cycle assessment
- Environmental communication
- Environmental aspects of product design and development
- Environmental aspects in product standards
- Terms and definitions
- Greenhouse gas management and related activities
- Measuring the carbon footprint of products.

International Organization of Standards (ISO) published various standards that form ISO 14000 Series. Information regarding the scope and aim of the published standards of ISO 14000 families can be stated as the following:

ISO 14001: Can be named as the world's most recognized framework for environmental management systems (EMS). Its aim is to help organizations to manage better the environmental impact of their activities and to exhibit comprehensive environmental management.

ISO 14004: Complements ISO 14001 by providing additional guidance and useful explanations.

ISO 14020: Addresses a range of different approaches to environmental labels and declarations, including eco-labeling, self-declared environmental claims, and quantified environmental information about products and services.

ISO 14031: Helps organizations to evaluate their environmental performance by delivering guidance on how to do performance evaluations.

ISO 14040: Provides guidelines on principles and conduct of Life Cycle Assessment (LCA) studies.

ISO 14063: Provides guidelines and examples on environmental communication which helps companies to make the important link to external stakeholders.

ISO 14064 parts 1, 2 and 3: Provides a set of clear and verifiable requirements to support organizations and proponents of Greenhouse gas (GHG) emission reduction projects with international GHG accounting and verification standards.

ISO Guide 64: Provides guidance in stating environmental aspects in products standards. Primarily, it targets standard developers but also useful for designers and manufacturers.

ISO 19011: The auditing standard ISO 19011 is a useful tool for assessing whether an Environmental Management System (EMS) is properly implemented or maintained. It provides guidance on principles of auditing, managing audit programs, the conduction of audits and on the competence of auditors.

Furthermore, International Organization of Standards (ISO) states that listed ISO 14000 standards can be used independently from each other in order to achieve environmental goals, although the ISO 14000 standards are designed to be mutually supportive. ISO 14000 family of standards delivers management tools for organizations to assess their environmental performance and manage their environmental aspects. International Organization of Standards (ISO) claims collective usage of these management tools can create significant tangible economic benefits in addition to distinct environmental ones. These benefits can be stated as the following,

- Reduced raw material/resourceuse
- Reduced energy consumption
- Improved process efficiency
- Reduced waste generation and disposal costs
- Utilization ofr ecoverable resources.

6) Principles of Green Engineering

The development of modern day technology leads to the new designs of sustainable waste treatment processes. The Principles of Green Engineering will help coordinate the development of green designing process that is sophisticatedly combine from the small decompose process of molecules, materials, product to the overall complex systems (Anastas and Zimmerman 2003).

The green engineering methods are not just a set of rules; instead they are like set of methods which can be adopted to succeed in implementation of sustainable design process. Optimization of an unsustainable production line is important to eliminate the problem that has caused to the logistics, economic and institutional system. To overcome the problems old process should be changed to new green one, by reconstructing the whole logistics system. The green principles should be implemented from top to bottom in order to get impressive effect. The principles can be stated as follows (Anastas and Zimmerman 2003),

Ensure to become inherently nonhazardous as possible.

It is not economically and environmentally sound to reduce or limit the hazardous effects of inherently hazardous materials. This can only be done by utilizing excess amount of capital, material, energy resources and time. So for restricting usage of these capital resources designers should consider designing products in such a way that their material inputs and outputs should be inherently non-hazardous as possible. Inherently hazardous material can lead to:

- Additional purification and cleanup steps to remove hazardous inputs.
- Safety precautions include round the clock monitoring and containment of material with eventual requirements of permanent storage and disposal facility.
- Extra steps in monitoring and handling results in the higher expenditures of product life cycle which can be incorporated in final product.

Prevent waste instead of treatment.

Waste generation and handling relates to consumption of money, time and efforts. Additional investment can be required for monitoring and handling different types of wastes. Waste production can be avoided and prevented whenever possible most obvious cause of waste generation is the result of faulty design of process in company. Energy based fuel systems also produce wastes resulting in greenhouse gases and particulates released in atmosphere resulting in climate change. Energy generation systems can be designed to prevent if not reduce the waste along with treatment efforts.

Reduce energy and material consumption in separation and purification.

Separation and purification are the two techniques which requires extra amount of capital and time. In some production processes toxic elements are released in atmosphere. To counter those elements first responsibility comes on designers in order to develop product design and suggest materials which are easy to identify.

Maximize system efficiency.

Time, space, energy and materials are important components of a production system which requires an effective management system. This management system results in the higher efficiency of production system by reducing the wastage of material, time and storage space.

Supply should be equal to demand.

In order to avoid extra handling of raw materials and finished goods, products should be produced according to demand. This helps in reducing over production which directly relates to lower resources and time usage. This is JIT strategy which is used in LEAN manufacturing system and can also be used in Green manufacturing system.

View complexity as an investment.

In today's world when advanced renewable processes are available still recycling process can be problematic or ineffective. This results in waste management complexity. The complexity depends on various steps ranging from raw materials to end customer usage. Brown papers is a good example waste management as considered as user and environment friendly they required a lot of time and energy in recycling process. Decomposition can be easy for these bags but wastes is still problem when comes mass production.

Design durable rather than immortality.

Durability is first priority of the customers which they call good quality. But when it comes along with green production processes, durability of products and its associated materials should be long lasting but not extremely long lasting as this can cause the treatment problems for the material as indestructible solid waste. Products with long lasting life cycle should have proper maintenance in order to have healthy life cycle to reduce excess cost of waste and time.

Design according to requirements minimizes excess.

Product design should be designed according to customer requirements rather than adding excess features. For overcoming this problem first the right idea should be developed cause if the idea is unrealistic than it will be a big problem during or after production. Lighting a match is good example of product design, the main feature of the match is to light on first attempt and light the fire but if producer produce a match that can last for 5 minutes after lighting than it is not a wise product design with respect to the cost of the product.

Minimize material diversity in multi component product.

Minimization of material diversity can be analyze at ground level during process development, which makes the recycling process easier and requires less amount of time and, money and resources. Single component recycling system is better instead of various component recycling systems resulting in fewer amounts of resources, investment and time. Car manufacturing industry is a good example in this case. During car manufacturing polymer is a major material for producing different components according customer order, resulting in money and resource savings due to reduced operations.

Integration of energy and material flows.

When production system is redesigned the outline of existing system must be reserve, as it is easier to use the same production resources, material flows and area. When a new design is produced then it should match the existing facility this concept has to be in mind by designers. This saves time and resources as the reordering of material is avoided. Through this principle reuse of energy can be possible by using hybrid and cogeneration power system. The basic idea is that energy is collected at exhaust end and injected back in the same system to produce energy.

Design for commercial afterlife.

Products with outdated technology can be discarded according to customers satisfaction, this scenario mostly depends on the current trend not the life cycle or failure of products. Most important example includes mobile phones, laptops, computers, TV etc. Separation of reusable parts are dynamic solution as these parts can be reused in new. This refers to the

product after life plan which can be utilized in design phase, this plan can be supplemented by convenient separation products which are easy to decompose and recompose and they also suits the recycling the manufacturing process. This results in lower amount of resources and time in product manufacturing.

Use renewable rather than depleting.

If waste reduction is not possible than another alternative can be renewable resources which is a better option. Production processes will not be dependent on material and management systems or be sustainable. One of the most common examples of renewable source is biological material such as feedstock; reusable material can be made as bio-plastics by non-biological material.

3.4 KPI and Environmental KPI

Key performance indicators (KPI's) are the measurement tools, which assists organizations in defining and measuring their progress towards their organizational goals. KPI's are considered as a critical element in measuring success of an organization or a particular business activity. KPI's are only successful when the organization's mission is defined; all stake holders are identified and defined its goals.

Selection of KPI's is an important step and some considerations must be taken, which includes,

- They reflect organizational goals
- They must be key to success
- They must be measureable.

Selection of KPI's should be done for long term, as the goals of a particular KPI may change under the influence of organizational goals change or it proceeds towards goal accomplishment, but the definition of what KPI's are and how they are measured do not change.

F. John Reh (2012), states that environmental Key Performance Indicators (KPIs) or Green performance indicators provide organizations a tool for measuring their environmental performance. E-KPI's are quantifiable metrics which reflects the environmental performance of an organizational performance in the context of achieving its wider goals and objectives.

In today's world, the impacts of environmental matters are creating their marks on business performance and will continue to do in future. For example, bad management of energy, natural resources or waste can hinder current business performance; unable to plan for a future in which environmental factors are likely to be significant may risk the long-term value and future of a business (UK guidelines).

In order to achieve a successful performance system, it is necessary that the performance is linked to the strategy and vision of the organization. In order to generate this link, one

acquires a KPI profile which can be used as a standard for the alignment of the organization's strategy and performance objectives.

3.4.1 Definition of Key Performance Indicators

According to Pekeliling (Malaysia et al, 2005), Key Performance Indicators are referred to as a basic performance measurement. Another definition comes from a business measurement expert, David Parmenter (2002). He defines KPIs as quantifiable measurements, agreed to beforehand, that reflect the Critical Success Factors of the company, departments or projects. Masilamani (2005) presented her definition of KPI's as a relative measure of the performance of an organization. KPI's can also be used to indicate the performance of specific and focused activities in the organization which could directly affect the value of that organization.

Pekeliling (Malaysia et al. 2005) looks at KPI's as something that one can measure continuously. Another aspect is that KPI must be few in number, probably less than ten. He also believes that in order to do well in performance measurement, the company needs to understand its critical success factors so that it may increase business with key customers. Furthermore, Pekeliling states that, one of the main distinguishing characteristics of a true KPI is that it is monitored on a daily basis by the senior management team.

3.4.2 Key Performance Indicator in Practice

Key performance indicators represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of an organization (Parmenter, 2007). A set of KPI's will therefore, be effective in coordinating and directing action within an organization. The KPI's reflect a balance between cost, quality, quantity and time. Balanced measures provide insurance of one KPI working against another. These indicators must therefore, be critical factors which can immediately alert the manager if something goes wrong.

As mentioned earlier, KPI's are a performance management tool, containing basic elements of measures and targets. The application of KPI's will assist an organization to be focused on key areas where performance is critical for achieving the vision, mission and objectives of the organization. Performance needs to be measured and KPI's provide the link to shift between performance measurement and strategic performance measurement. The act of simply measuring performance would not provide a proactive perception of goal and strategy achievement. Likewise, KPI's do not have meaning, unless they are linked to an evaluation system (Seang, 2003).

KPIs are quantifiable measurements that gauge the outcome of a critical success factor, goal and objective or performance (Bauer, 2004). KPIs do not often change, as it is usually long-term considerations. The definition of the KPI must stay the same from year to year. Critical success factors (CSFs) focus the attention on the key dimensions of performance that the enterprise must excel at if it is going to achieve its goals and meet customers' requirements (Anon, 2007a:9). Limited in numbers, CSFs emphasize the activities and processes that will have the greatest impact on performance that will drive accomplishment in supporting areas.

3.4.3 Why Key Performance Indicators should be utilized

Reh (2005) states that KPI's will help an organization define and measure progress towards organizational goals. Once the mission statement has been analyzed, stakeholders identified, and goals defined, KPI's are set in place so as to measure progress towards goals. KPIs are a performance management tool and they should not just act as visual metaphors. The developer should understand what constitutes KPI's that could deliver a long-term value-added tool to the organization.

KPI's reflect strategic value drivers according (Eckerson, 2004) to achieve organizational goals. Value drivers mean activities that, when executed properly, guarantee future success. Value drivers could help an organization to move in the right direction in order to achieve its organizational goals, for example, high customer satisfaction or excellent service quality. KPI's, in most cases, are non-financial. It can never be a monetary measure (Parmenter, 2007). KPI's are "leading" and not lagging performance indicators. The value of data is directly proportionate to how fast a business can react to it. An organization needs to be responsive to the information they have access to. It is important that the person responsible needs to have the capability to identify how they are performing so that they can react to it.

KPIs are quantifiably based on valid data and standards. Most organizations have their own set of metrics and standards for performance measurement. But it can take organizations months and maybe years to come up with the end results. Therefore, with the use of KPIs, the existing sets of indicators could always be quantified as relevant to the organization's need. However, it is important to accurately define the KPI's and maintain the same definition in consecutive years. It is important that the KPI is understood by those who are concerned and have the authority to take specific action to accomplish their targets (Parmenter, 2007).

A major benefit of KPI's is that the key issues are addressed and by using a dashboard, the results are visible. They do not need to analyze rows of data on spreadsheets or reports to come up with the same result (Anon., 2009). When an outcome is monitored and trended with a KPI, the resulting figure tells one the process performance effectiveness. The KPI should be an accurate, honest reflection of the process efficiency in delivering the outcome. With a reliable KPI measure of performance, the effect of a change made to a process, or a new strategy implemented, is then reflected in the KPI results produced. KPIs can offer many perspectives on an event. It can permit intense focus and scrutiny, it can detect changed conditions, it can score performance, it can indicate a change from plan, it can detect potential problems and it can drive improvement. Change to a certain operation can be monitored and the reflected KPI will echo if the change improved the result. Once the effects of a change can be monitored reliably, reputedly and accurately by KPIs, it is reasonable to use the KPI as a tool to improve the ongoing process performance. Simply introduce the test change into the process and monitor its effect with the KPI. Keep those changes that work and discard those changes that do not produce suitable results (Anon., 2009).

KPIs lead to positive actions and provide the key to organizational success. KPIs should generate the intended action and thus, improve performance. Only those factors that are essential and critical to the organization reaching its goals are selected. It is important to keep

everyone's attention focused on achieving the same KPIs. How to motivate people to reach the KPIs targets? The top management could use KPIs as a carrot. Post and show the progress of KPIs everywhere in the organization such as the main entrance, pantry room, on the walls of hallways, meeting rooms, staff areas, or even on the organization's website. The future success could be realized if the top executives give their full commitment. When KPIs cascade throughout the organization, it will enable everyone to march together on the right path (Parmenter, 2007).

3.4.4 Pitfalls of KPIs

In practice, overseeing Key Performance Indicators can prove expensive or difficult for organizations. Some impacts, such as staff morale, may be impossible to quantify. Another serious issue in practice is that once a KPI is created, it becomes difficult to adjust to changing needs as historical comparisons will be lost. Conversely, an uncertain KPI is often created because history does exist. Furthermore, if a KPI is based only on in-house practices it may be difficult for an organization to compare with similar organizations; yet often, businesses with similar backgrounds are used as a benchmark for KPIs (Anon., 2007).

a) Pitfalls when developing KPIs (Anon., 2007)

- Measures are not linked to organizational strategy from top.
- Measures are not driven into organization from bottom which breaks the linkage with overall strategy.
- Too many measures create lack of focus on what is really critical to manage the business.
- Not enough critical measures results in missing information vital to operations.
- Focusing only on the short-term measures.
- Conflicting measures. Sub-optimizes staff or organizational performance.

b) Pitfalls when monitoring progress (Anon., 2007)

- Measuring progress too often, result in unnecessary effort and excessive costs, resulting in little or no added value.
- Not measuring progress often enough, result in unknowing about potential problems until it is too late to resolve easily.
- Collecting too much data, result in a mountain of data causing confusion what to do.
- Collecting inconsistent or unnecessary data. Critical to understand what the data will look like, when it will be collected, at what frequency, by whom and what it means, up front.

c) Pitfalls when evaluating data (Anon., 2007)

- "Dumping the data" (i.e., reducing the value of impactful data). Too much data roll-up (summary) can mask the impact of potentially significant events or trends.

d) Pitfalls when determining improvements (Anon., 2007)

- Driving the wrong performance. Be careful that the measure(s) you select will result in the desired result. Remember the "law of unintended consequences".
- Encouraging competition and discouraging teamwork. Measuring vertically (stove-piping) frequently pits one internal organization against the others. Try to measure horizontally.
- Failure to base business decisions on data. Developing performance measures or collecting data only to comply with a requirement, does nothing to improve the position of the department, organization or enterprise.

Summary of Theoretical Framework

To summarize the theoretical framework, the basic concept of sustainability has been discussed above. Lean has been discussed in detail, explaining about its principles, lean waste and ways to prevent it by lean tools & methods and how it can be used to increase sustainability in production system. Similarly green manufacturing system has been discussed explaining about green wastes, key elements of green engineering which includes EMS, ISO-14001, eco audit etc. At the end of the chapter key performance indicators has been discussed explaining about its practice and utilization and their pitfalls.

With the knowledge gained from theoretical framework study, questionnaire is prepared for the case company to get relevant information.

4. Case Company

4.1. ABB (LUDVIKA)

The ABB Group, a leading company in power and automation technologies, employs about 124 000 people around 100 countries. ABB offers a wide range of innovative high-voltage electrical equipment such as circuit breakers, capacitors and filters, disconnections, earthing switches, power transformers, instrument transformers, surge arresters, switchgear cubicles etc.

Various kinds of high voltage electrical equipment such as circuit breakers, capacitors and filters, disconnections, earthing switches, power transformers, instrument transformers, surge arresters, switchgear cubicles etc; are tested at the High Power Laboratory in accordance with the international or regional standards.

ABB offers a wide range of innovative high-voltage products up to 1200 kV that help enhance the reliability, efficiency and quality of power while minimizing environmental impact all complemented by a comprehensive service offering. They develop and manufacture a comprehensive range of products and solutions which improve the power quality of electrical networks by eliminating disturbances and improving power factor.



Fig 5: ABB Ludvika's HVDC Capacitors

4.2. Company Process

ABB in Ludvika has been a leading center for development and manufacturing of various high voltage transmission equipment. ABB Management has utilized Value Stream Mapping (VSM) which is a lean tool for visualizing the manufacturing process. This proved to be vital method for determining problems and effectively solving those problems in the manufacturing line. Capacitor manufacturing VSM as shown below in fig.6 clearly depicts the flow of the process line from the raw material till final delivery to the customers.

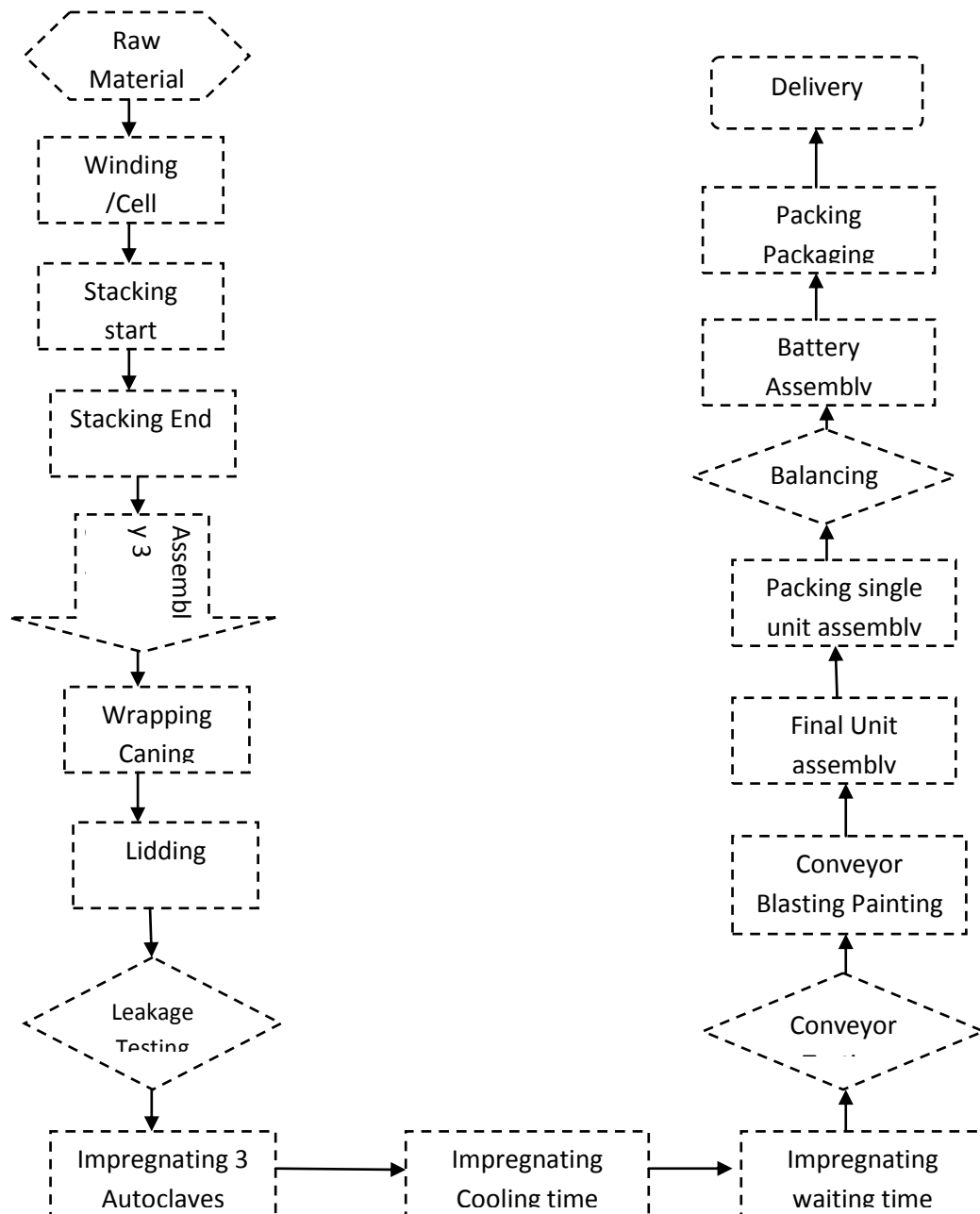


Fig 6: Production and Process flow at ABB Ludvika

4.2.1. Process Description

Winding Cell

Winding cell is the first and important stage in producing capacitor. In winding cell elements are produced which are the core component of capacitor for conducting electricity. Element is comprised of aluminum sheet sandwiched between two layers of polymer sheets. Thickness of the element depends on capacity of the conductor as ordered by the customer.

Waste generation at this stage consists of rejected elements produced due to polymer and aluminum foil roll change.

For calculating productivity of this cell management has been utilizing a KPI which is,

Winding: Number of elements and productivity as per calculated operation time. Down time also added with available time of the winding machine (availability).

$$\text{Productivity} = [\text{number of elements}/\text{calculated operation time}] * 100$$

Stacking

Stacking is the second stage where elements produced in winding cell are put together and connected with tin strips which carries ICs for flowing of electric charge.

Waste generation at this stage contains metal strips or fused ICs. Metal strips are sent back to suppliers for recycling while ICs are discarded through incineration process.

Wrapping and Canning

It is the third stage where stacks are wrapped with paper sheets and afterwards put inside metal cans. Packing paper is the only wastage which is produced in very low quantity.

Lidding

Lidding is the fourth stage where ceramic hoses are connected to the stacked metal cans. After hose connection cans are welded and sealed off. Faulty metal connectors and ceramic wastes come out as a waste at this stage.

Impregnation

Impregnation is the fifth stage where sealed off capacitors impregnates for 20 hours in autoclaves. After impregnation capacitors are cooled off for 12 hours. At this step wastes effluents comes out as wastage.

Testing and Painting

After impregnation capacitors are washed and tested for leakage detection. Capacitors are then moved towards blasting and painting area where the capacitors are surface finished through blasting process. Blasting is done through steel bullets in a concealed chamber.

Blasted capacitors are then moved in painting chamber, where a computerized programmable robotic arm is used to paint the capacitors, in which they use steel bullets for surface finish and then painted through robotic arm. At this station some amount of steel bullets are lost and there is some leakage of VOC particles into atmosphere, the washed chemical is treated after washing.

For determining the defect rate of painted units management has been using KPI which is,

Painting / Blasting: Number of painted units and number of units with quality problems

$$\text{Defective Rate} = [\text{No of defective units}/\text{No of finished units}] * 100$$

Assembly and Delivery

This is the final step where finished capacitors move towards assembly area where they are assembled in form of battery according to customer requirements. After assembly packing takes place for final delivery to customers.

Utilization of Lean Tools

Capacitor manufacturing process at ABB Ludvika plant is a semi-automated process, which emphasizes on human expertise on almost all stages of process. Before the economic downfall ABB was following mass production system to produce products in large quantity in low cost, but after economic downfall it becomes a problem for the company to manage big inventory of raw material and products produced. To overcome this problem higher management initiated a plan to implement Lean tools to achieve higher production and human labor efficiency, so that competence should be achieved. 5S, JIT, Single piece flow, Value stream mapping are the Lean tools which have been utilized till now by the management for resource efficiency. For standardizing the manufacturing operations ISO-9001 has been implemented so that quality control should be achieved.

Utilization of Environmental Tools

For ABB Ludvika, environmental efficient development is also on focus along with production efficiency. ABB management is working on to develop products and processes which have the most efficient energy and raw material usage, and waste and residual products are minimized over the products' life cycles. For enhancing environmental performance ABB management has implemented various environmental systems on different levels of organization. Environmental Management System (EMS), ISO 14001, OHSAS-18001 is the environmental systems which have been implemented at the manufacturing unit. For monitoring these environmental systems audits, follows up and reports are systematically perform.

For visually monitoring the environmental aspects of the process management has been utilizing a greenhouse diagram, which shows utilization of raw material and energy, emissions, residues and recyclable products.

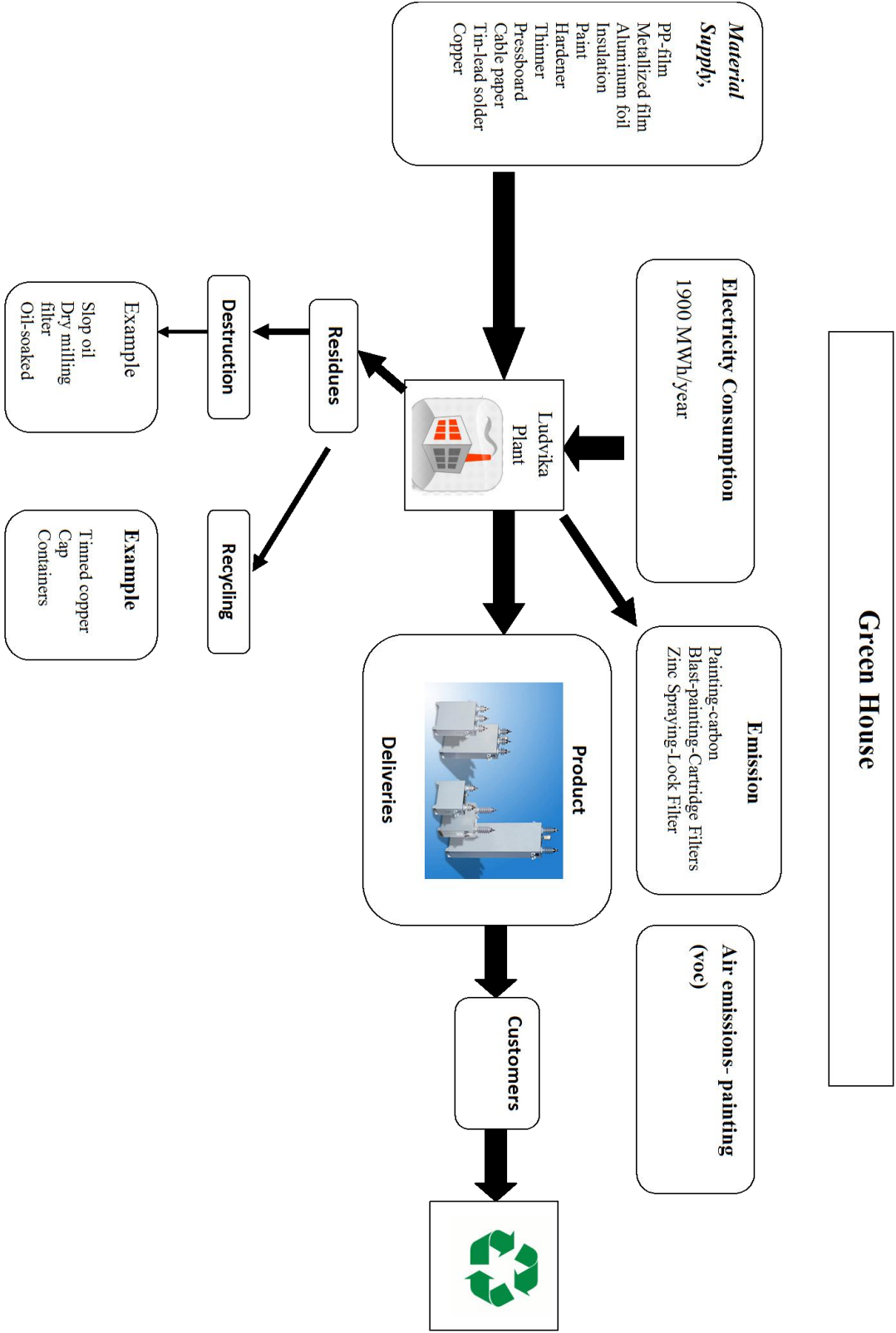


Fig 7: Green House at ABB Ludvika

The green house of ABB Ludvika shows a sustainable approach that focuses on the environmental impact from products and service that should be seen from a lifecycle perspective. It was carried along from the first initial concept until the last part. Moreover, the technological development process, which is the composition of environmental demands and the active research and development, will be in focus.

5. Analysis

5.1. Implementation of Lean tools

In today's world industrial scenario, industries are gradually realizing the fact that lean production system improves the effectiveness of the existing production system through implementing the lean tools. Lean effectively reduces waste and non-value added operations on the production floor, making it an effective resource efficient system to counter the challenged of the current market demands.

The main challenge for effectively implementing lean requires trained or experienced team. Management should take proper measures to implement lean through change management and training of their employees.

Management of case company ABB ludvika has formed a team of 2 members for lean implementation on the production floor and supply chain. The pace of implementing lean is quite slow as the team members are working on multiple posts rather than a full time lean implementation team. The main reason for slow implementation of lean tools on the production floor is absent of training of middle management and lower level employees.

For ABB it is evident that, the main reason for implementing lean is to improve their productivity, reduce lead time, inventory and waste which results in improve resource efficiency and helps to achieve sustainable operations.

ABB management has been able to successfully implement different tools which includes, 5S which helps to reduce unnecessary items to manage time management, one piece which involves small batches to be processed and moved at a time rather than big batches, value stream mapping which is helping management to identify flow problems and reduction of lead time, SMED (single minute exchange of die) which helped to reduce changeover time.

These lean tools can be more effective by training low level employees in order to get more impressive results through these tools. Sustainability is the key issue on which ABB is emphasizing on, these tools can supplement sustainable manufacturing known as "Green Manufacturing". Green manufacturing focuses on environmental issues caused by unnecessary utilization and wastage of material, emissions etc. On the other hand lean can contribute to Green by lowering down the wastage (material, energy and time) produced during production process, making the process cleaner and greener.

5.2. Implementation of Green Tools

Instability of environment has becoming a major concern due to the unnecessary utilization and depletion of resources, excessive emissions etc. Governments are taking legal initiatives to reduce the environmental impacts causing by companies through their material extraction, logistics, production processes and product after life. To overcome these legal issues companies are integrating green into their supply chain process. The main motive to practice green is to improve company performance, ensuring sustainability and production processes. This results in improve product quality and working condition, reduce cost and wastage etc.

The case company ABB Ludvika's management has been very keen towards sustainability, and has been working on and has unofficially implemented many core components of Green

manufacturing on various levels such as, EMS is a management system which helps organizations to spot their environmental issues and accommodate these issues under their environmental policy, ISO-14001 is an international standard which focuses on standardizing environmental performance of the organization and take economic benefits from it. OHSAS 18001 is a safety and occupational health management system for safety performance among the organization. For product quality issues ISO-9001 has been implemented so that standardized operating procedures can be implemented on the production process.

ABB management has been very much emphasized on the sustainability issue, but the process is still long way to go as the management has mostly focused the sustainability issues inside the organization boundary. They have to take consideration on suppliers for the material extraction sources, solid waste management dealers, most importantly educating middle and lower management employees so that organizations green performance can be enhanced.

5.3. Utilization of KPI's and E-KPI's

Key performance indicators (KPI's) are the measurement tools which helps organizations to define and measure their progress towards their organizational goals. These goals include employee work performance, production performance, wastage etc. These are the KPI's which are related to boundaries of the organization while E-KPI's (Environmental KPI's) relates to the outside of the organization boundaries which includes raw material mining, carbon dioxide and radiation emission, product and material recycling etc.

ABB management has been utilizing two kpi's on their production floor as described in section 4.2.1. The first kpi at winding cell is totally related to productivity of the cell, while the kpi which has been used at blasting and painting cell is defection rate of the product this can be seen as an E-KPI, as it is dealing with product defection rate and product wastes created at this step.

By analyzing these kpi it can be seen that management has not been utilizing proper kpi's and E-kpi's for management and environmental issues. For determining environmental impacts caused by production facility and management activities different E-kpi's can be utilized to fulfill the organizations objectives.

5.4. Sustainability approach at ABB Ludvika

In ABB sustainable development is one of the most important factors which have been emphasized by organizations higher management. Aim of sustainable development at ABB Ludvika is to maintain customer's value and profitability in long run. Through balancing and combing three factors of sustainability which are environmental, social and economic responsibility, sustainability, an analysis has been made on the sustainable approach of ABB which can be seen in fig 8,

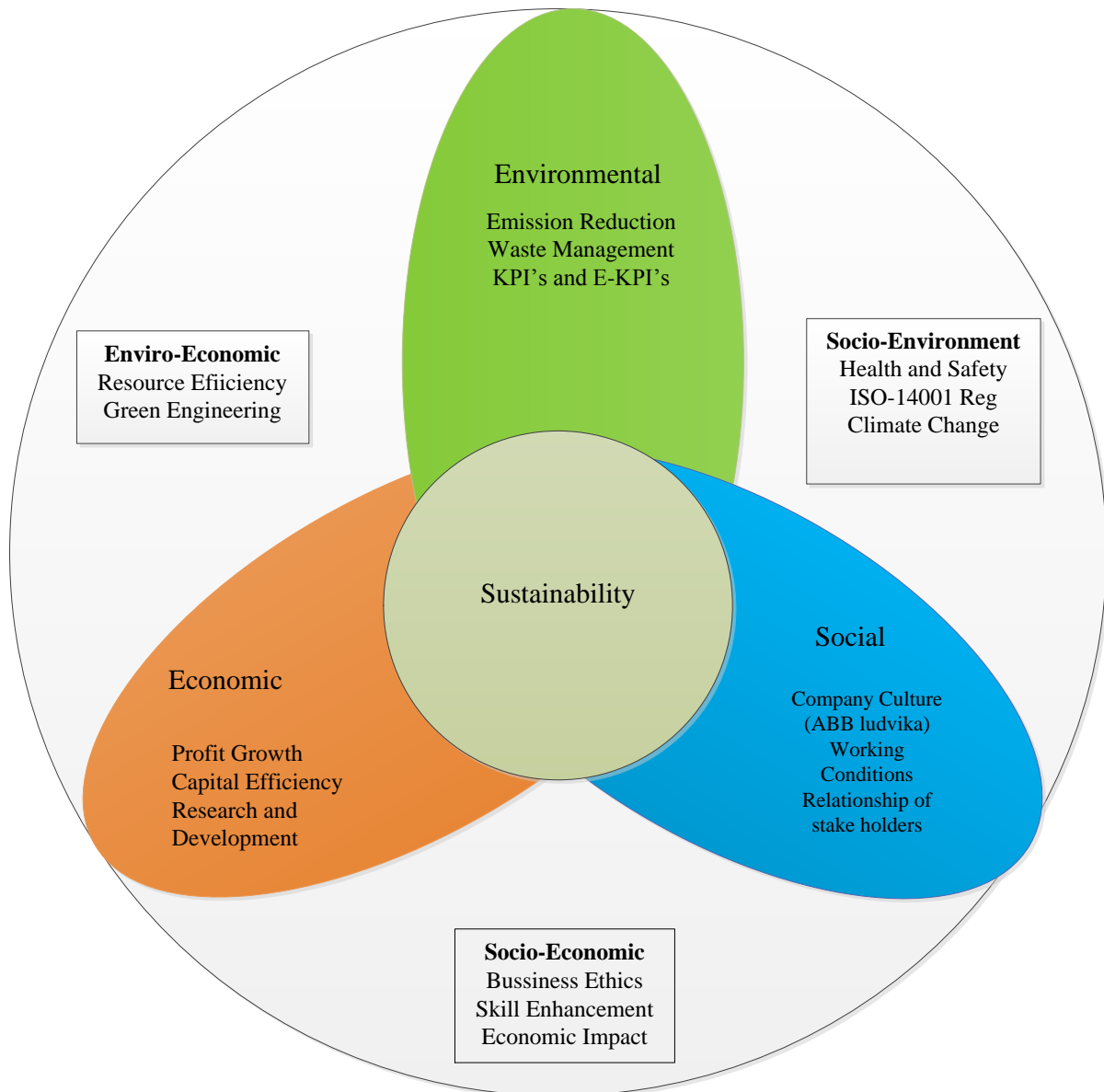


Fig 8: Holistic view of the sustainability approach at ABB

Environmental Responsibility

Environmental responsibility activities mostly emphasizes on how to minimize the environmental impacts throughout lifecycle of product and product processes. Emission control, waste management, selection non-toxic materials and recyclability of products and lastly used materials must be implemented and concerned. ABB Ludvika has implemented environmental responsible activities which include,

(a) Waste Management

In ABBA Ludvika, wastes from different production steps are separated by types. All of the wastes are separated manually by labors. This waste includes winding elements composed of plastic and aluminum sheets, metal strips, paper waste, used filters and ceramic waste and toxic spills. All the wastes are separated and categorized, in order to be moved to different

places. Recyclable wastes are gathered and transferred to recycling suppliers, non-recyclable wastes such as winding element and used filters are shipped to energy production facility in order to be used for heating purpose. Waste water and toxic spills will be transferred to plant treatment plant.

(b) KPI's and E-KPI's

Key performance indicators and environmental performance indicators are the performance measures of the ongoing process in the organization. Company management has not been very much active in utilizing or developing KPI's or E-KPI's as only two KPI's have been in use in production department, while no E-KPI has been in use to monitor the performance of the system activities.

Economic Responsibility

ABB power products Group sets the target of increasing the profitable growth rate at least 5-7 annually. Key management priority remains as cost competitiveness, with the focus on global sourcing operational excellence initiatives and optimizing ABB's global footprint to better balance costs with market growth. ABB expects save approximately \$ 1 billion in costs in 2012. Technology and R&D remains core to ABB's long-term strategy, with growth in R&D investments expected to outpace revenue growth over the 2011 to 2015 period.

Social Responsibility

ABB Ludvika's social responsibility can be seen as internal and external ways. Freedom of speech, trust and empowerment are the business manners that have been offered for everyone in the company. While interviewing one of the interviewees said that he feels very enthusiastic to work as she has freedom of thinking and most important his boss door always open for any question, this creates a good working condition. While implementing or applying new concepts and innovation or new ways of thinking which is completely differs from traditional business activities into firms, employee's attitudes adjustments sometimes is a huge obstacle as they are familiar with their regular working and old ways of thinking. External social responsible activities mainly concentrate on building up long-term relationship of stakeholder's. The company also has well-developed relations with such group as universities, research institutions, media, non-government organization and government agencies. At this point, the company can gain advantages and innovation from competitiveness by cooperating with each other organization for developing new products and product process.

The balance between environmental and economic responsibility

The company has been concentrated much on its product development, daily activities and production process in order to balance environmental and economic responsibility activities. In this case the balance is the ABB Ludvika can maximize its benefits by innovatively minimizing its cost without any impact of environment.

The balance between social and economic responsibility

Diversity is an accelerator for innovation and a source of profitability and international competitiveness. The company's diverse workforce relies without discrimination on some

parts of the Code of Conduct which focus on mixing the workforce of genders, people of many generations, people from ethnically and racially diverse backgrounds. Innovative business solutions can be generated by intersectional ideas and various perspectives of the diverse employees. In long-term success ABB Ludvika always find new business opportunities in keeping company as competitive in the market. By the holistic view figure ABB Ludvika has drawn the balance area between social and the economic responsibility and it means that it can generate benefits both factors economically and socially.

The balance between social and environmental responsibility

ABB Ludvika is an industrial company which has been stayed on those environmental regulations. Since global warming and change in climate became a globally social problem, many environmental regulations and legislation released, in order to get industrial companies to strictly follow it. At present company ISO14001 has been implemented into all business activities. ISO14001 describes controls for those activities that have an effect on the environment, ISO14001 for the environmental management of businesses. This environmental regulation has forced the company to adapt or even change new production processes, plants management, new concepts of product design, etc.

Safety and health OHSAS 18001 is also in the company's core value. Production processes internally and the company's plants design have been environmentally well managed in such way for minimizing negative impacts and accidents rate. Also, products and services externally are not allowed to create any kind of environmental and negative social impact.

6. Suggestions

KPIs have special meaning to work place learning by considering organizational strategy, structure, and systems (e.g., job system and reward system). KPI bridges the gap between an organization's mission and vision and its employees' targets (Ran & Wang, 2008). We seek to find out the factors that influences or contributes to the green production system in an organization

6.1. Design Mechanism for E-KPI's

KPI's and E-KPI's measurement is not just a scientific or mathematic calculation with set of formula. Measuring KPI's helps us determine how well our business is achieving its business objectives and areas need of improvements. A three step mechanism has been proposed for the case company to develop KPI's and E-KPI's according to company's objective, so that company's objectives should be achieved systematically and without confusion.

Step 1

Select the organization's environmental targets, objectives and range. Decide what objectives management wants to measure and at what point achievement of the objective begins.

Example: If we want to measure average change over time, this is target. A set of range one to five (each time a changeover is performed) to be excellent, while six to ten is good and over ten is poor.

Step 2

For measuring E-KPI's and KPI's management have to set up the time period. This can be done by choosing between a repeating time period, a rolling time period or a fixed time period. A repeating time period must take place at interval over a period of time. Example: KPI's and KPI's can be measured on a daily, weekly or monthly time interval over period of time.

Step 3

Assign numerical values to the categories of the KPI's range. Create our own scale of measurement for the KPI's and E-KPI's we are measuring. Example: Assigning numeric value from one to five, where one is poor and five is the best.

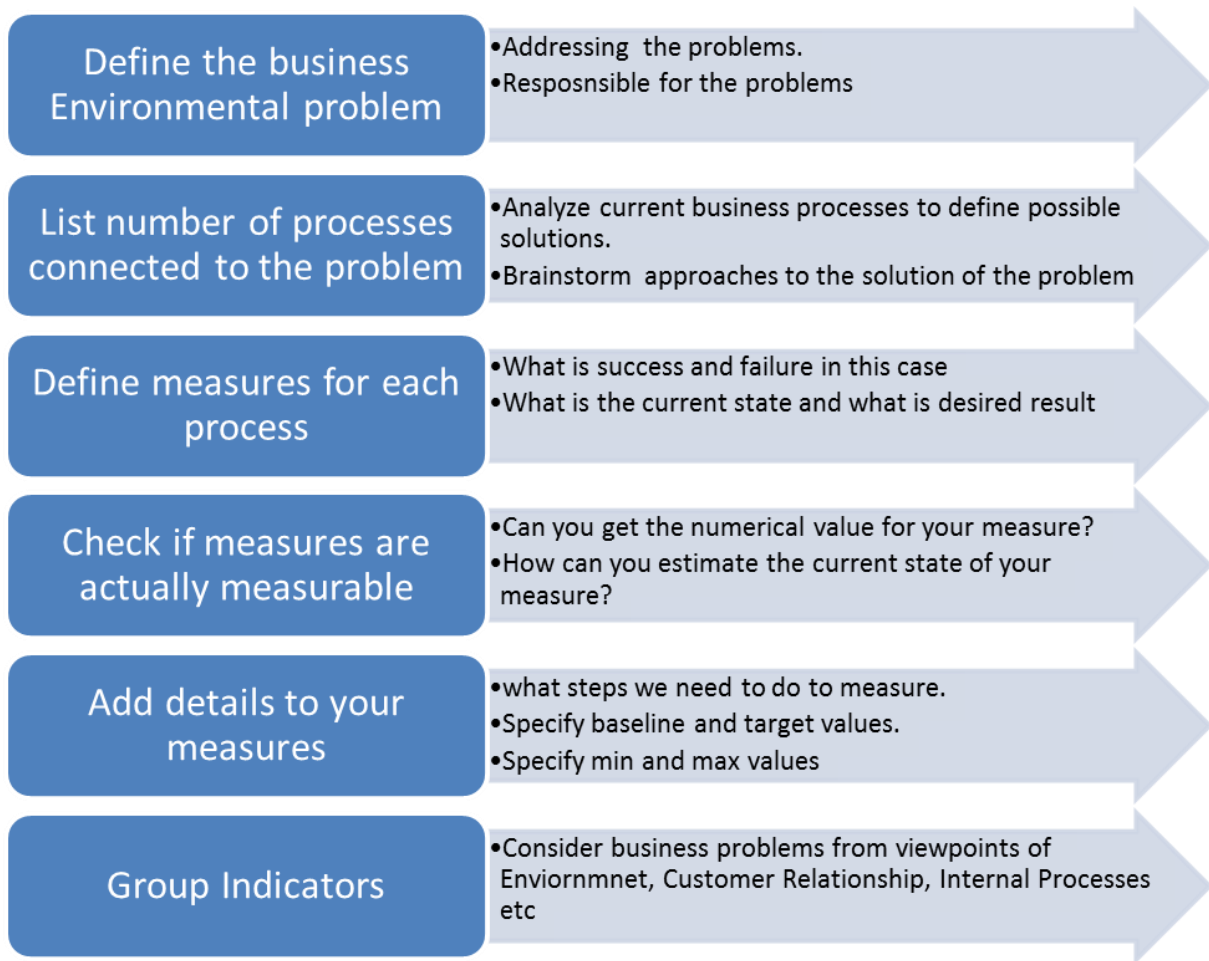


Fig 9: Holistic approach for designing Green KPI's for ABB Ludvika

6.2. Suggested E-KPI's

1. Carbon Footprint

Carbon footprint can be divided into primary and secondary footprints. Primary footprint can be composed of the emission of direct gases produce by the fossil fuels for energy generation and transportation of the company employees (Air travelling). For secondary footprint emission of greenhouse gases can be composed of transportation of raw material and finished products.

Emission of CO₂ = Primary footprint + Secondary Footprint

Primary = CO₂ (Electricity) + CO₂ (Air travel)

Co₂ (Electricity) = [total fuel bill / (price per/gallon)] * emission factor of fuel

Co₂ (Air Travel) = total distance travelled in km * (direct emission per km * indirect well-pump factor * atmospheric radiative forcing factor)

Secondary footprint = Raw Material or Product Transportation

Co2 (Transportation) = no. of vehicles * [(no of km driven/month)/fuel efficiency]*Co2 emitted per gallon * emission of GHG other than Co2

Through calculating these factors a total amount of CO2 generation can be predicted, directly and indirectly by the company activities. This KPI for CO2 calculation is a customized KPI for ABB Ludvika as per according to their activities and cannot be applicable to every industry or company.

2. Recycling Rate (%)

General product or waste recycling percentage measures the proportion of the products that company recycles or reuse. If reuse is not suitable for a product, then recycling is the next method of priority. For determining recycling rate company have to calculate total waste generated which includes, recyclables, untidy parts and trash. As mentioned below total waste generated in inversely proportional to amount of recyclables and untidy parts. With this formula we can calculate the waste percentage through recycling.

Total Waste Generated = (Recyclables + untidy parts + Trash)

Trash is used only in total waste generated because it is for disposal of waste.

Untidy parts are those which do not meet the customer requirements.

Recycling Rate (%) =

[Amount of Recyclables + Amount of Untidy parts collected for recycling / (Recyclables + Untidy parts + Trash)] X 100

By knowing the recycling rate in certain way helps you plan your development and progress. Even it will be helpful for the company by displaying how well it is performing in certain particular areas. The following formula is applicable for both waste recycling and product recycling percentage.

Product Recycling Rate (%)

Product Recycling Percentage measures the proportion of the products a company sells that is recycled or reused.

Product Recycling Percentage = [Amount of products recycled or reused / Total amount of Products sold] x 100

Waste Recycling Rate (%)

Waste Recycling Rate measure to what extent a company is able to recover waste it is generating for reuse or recycling.

Waste Recycling % = [Amount of recyclables / Total waste produced] x 100

3. Waste Reduction Percentage

Waste Reduction rate is a measure of the level to which a company is able to reduce the waste it is generating as part of its operations. The unit for measuring waste is kg/hour or tons/week.

For calculating waste reduction percentage a time limit has to be adjusted, so that comparison can be made between two time periods due to the precautions done taken by the management. This time period can be adjusted to no. of days or weeks.

Waste Reduction Percentage = [Wasted Raw Material (Time period a) / Wasted Raw Material (Time period b)] x 100

To determine how the generation of a certain waste from process has changed over time by reference to the production unit output. A good measure of waste reduction might be on a process basis, such as the waste per day or week or month.

[(amount of waste generated in the previous month /production output)/ (amount of waste generated in present month / Production output)]X100

Waste reduction for plant with more than one waste producing operation or process with the following formula overall percent waste reduction.

Waste reduction Total = (Mn/Mtot) WRn

Where as

Mn = Amount of waste from n number of waste producing operation or process

Mtot = Total amount of waste generated in operation plant.

WRn = Waste reduction percentage from n number of waste producing process or operation.

6.3. Comparison of proposed KPI with general KPI

Table: 2 Comparison of General Carbon footprint VS Proposed Carbon footprint KPI

Carbon Footprint KPI	
Proposed KPI	General KPI
<p>Emission of CO₂= Primary footprint + Secondary footprint</p> <p>Primary= CO₂ (Electricity) + CO₂ (Air travel)</p> <p>Co₂ (Electricity) = [total fuel bill / (price per/gallon)]* emission factor of fuel</p> <p>Co₂ (Air Travel) = total distance travelled in km* (direct emission per km* indirect well-pump factor* atmospheric radiative forcing factor)</p> <p>Secondary footprint = Raw Material or Product Transportation</p> <p>Co₂ (Transportation) = no. of vehicles * [(no of km driven/month)/fuel efficiency]*Co₂ emitted per gallon * emission of GHG other than Co₂</p>	<p>CO₂ = (Total Amount * (CO₂ Emission Factor * Heating Value) * Density).</p>

Carbon footprint is an important measure in calculating organization’s carbon dioxide produced by different activities. General purpose KPI can be effective for determining simple carbon footprint, but when comes to complex and thorough calculation for carbon footprint a new KPI have to be develop according to the scenario of the respective company. As shown in the above table a new KPI has been proposed for ABB Ludvika, which is the case company according to their activities which includes carbon dioxide produced by electricity production and air travel by company employees in primary part, while in secondary part transportation of raw material and finished products by vehicles has to be determined. When we compare this to the general purpose KPI for carbon footprint we can see that it will impossible to calculate the overall carbon footprint of the company activities. Due to this reason the proposed KPI can be a good option for determining ‘carbon footprint of the company.

Table: 3 Comparison of Proposed Waste Recycling VS General Waste recycling KPI

Total Waste Recycling	
Proposed KPI	General KPI
<p>Total Waste Generated = (Recyclables + untidy parts + Trash)</p> <p>Recycling Rate (%) = [Amount of Recyclables + Amount of Untidy parts collected for recycling / (Recyclables + Untidy parts + Trash)] X 100</p> <p>Product Recycling Percentage = [Amount of product recyclables + untidy products / (Recyclables + Untidy parts + Trash)] x 100</p> <p>Waste Recycling Rate = [Amount of waste recyclables / (Recyclables + Untidy parts + Trash)] x 100</p>	<p>Product Recycling Percentage = [Amount of products recycled or reused / Total amount of products sold] x 100</p> <p>Waste Recycling Rate = [Amount of waste recycled or reused / Total waste produced] x 100</p>

Waste generation from production lines effects environment and results in extraction of more resources if not recycled, this includes direct waste generation by production line and indirect through products manufactured. Recycling waste and products results in lower carbon emission and cash recovery for the company, which effects on environment in a way that new raw materials are not extracted for product manufacturing. In general product recycling and waste recycling are utilized as two separate KPI's but if closely monitored we can see that both contains recyclable and non-recyclable parts. For this reason in proposed KPI total waste has been composed of recyclable wastes, untidy parts which are not customer specifications and have to be broken down to be recycle and in the end trash which consists of waste which cannot be recycled and has to be disposed of permanently. For calculating recycling rate percentage amount of recyclables and untidy parts are added and divide by total waste so that exact amount of organizations recycle rate can be determined. After calculating total waste and recycling rate it is easy and clear for the management to calculate exact amount of product recycling and waste recycling rate as all the waste has been categorized separately.

Table: 4 Comparison of General Waste Reduction % VS Proposed Waste Reduction% KPI

Waste Reduction %	
Proposed KPI	General KPI
<p>Waste Red. % = [(amount of waste generated in the previous month /production output)/ (amount of waste generated in present month / Production output)]X100</p> <p>For more calculating waste from more than one process, Waste reduction Total = (Mn/Mtot) WRn</p>	<p>Waste Red.% = [Wasted Raw Material (Time period a) / Wasted Raw Material (Time period b)] x 100</p>

Waste reduction percentage is use for calculating waste generated on a certain period of time. General KPI for waste reduction percentage calculates waste reduction percentage by comparing waste generated on two specified time periods, but it does not put importance on the production produced on the same time of reference. For overcoming this shortcoming total production output has been added into the proposed KPI, so that actual amount of waste can be calculated on a certain period of time and counter measures can be taken in order to reduce the waste. Proposed KPI has been further strengthening by adding a sub KPI for units having more than one production line so that overall waste can be calculated.

7. Discussion

This section provides answers to the three research questions relying upon the analysis above and additional literature study. The discussion is based upon the analysis and theoretical studies from literature presented earlier.

What are the barriers and drivers in production process in attaining green manufacturing practices?

This part explains about different barriers and drivers of company's green manufacturing practices from literature study, case company interviews, survey and visit, we conclude that that following are the main barriers and drivers should be taken under consideration in case company.

Table: 4 Drivers of Green Manufacturing

Main Drivers for Green Practices	Description
Legal Requirement Green Image Global Marketing [2][3][4]	Pollution Control , emission trading and public perception of the company
Cost reduction benefits[5] Economic benefits Improved quality Level Green purchasing strategy[9][7][4][6]	Green practices contribute organization to attain benefits in economic and reduction of energy consumption
Customer awareness Demand for eco-friendly products [2][1][10]	Investors, customers and suppliers to be more aware about eco-friendly products.
Environment concerns Employee's motivation Ecological benefits Waste disposal problems[2][4][10]	Organizations should focus towards self-responsibility for sustainable development.
Scarcity of Resources Rapid industrialization Limited space available for disposal[5][8][9]	Availability of limited natural resources forces for contributing Green manufacturing
Corporate strategies to maintain market leadership[1][5][8][10]	Firms individual strategies for improvising their overall efficiency contributing to green manufacturing.
Good Customer-supplier relationship Compatible supply chain structure Efficient leadership of senior management[2][3][4][7]	Supporting infrastructure and individual ability of organizations also contribute a lot towards sustainable development of organization.

Improved technology of converting waste in to new product Satisfactory technological alternatives [3][4][10]	Allow ability consumption of re-cycled materials in manufacturing system give direction to green manufacturing.
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Table: 5 Barriers of Green Manufacturing

Main Barriers for Green Practices	Description
Lack of necessary management tools and skills Unawareness of customers[1][3][4]	No awareness of green trends and limited access to green literature
Uncertain benefits Hidden costs[2][5]	These are some of the de-motivating reasons which acts barriers for Green Manufacturing
Lack of Implementing Green Practices Market Competition and Uncertainty[3][4][5]	Market Competition and Uncertainty is very high due to global competitiveness, and varying customer's requirements
Lack of Quality of Human Resources Organisation Encouragement [2][3]	Lack of Quality of human resources means not recruiting well qualified and professionals
Recycling uncertainty in material recovery Difficulty in recycling for perishable products[3][4][5]	Green Manufacturing practice resembles recycling and it is not necessary to be 100%.

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Why it is difficult to measure and practice green in today's world?

The concept of Green practice and manufacturing is crucial in preserving our whole environmental and natural resources for present and also for our upcoming future generation. It is considered as high cost, a lot of difficulties and acquire full determination even though of all factors companies have taken initiatives for implementation of Green.

The difficulties to practice Green Manufacturing in today's world and case company are,

1. Resistance to technology advancement adoption

An organization having high experience in application and adaptation of related technologies will have much higher technology innovation (Gant, 1996) and organization will have higher innovative capability when knowledge can be shared more easily within the organization (Tsai and Ghoshal, 1999). Attaining Technology advancement with higher transferability and resistance of organization's advancement of technology adaptation is resistance to change. Barriers in organization explain that difficulty in implementing fundamental changes in the organization.

2. Lack of Organization encouragement

Proper training and education system are the basic requirements for achieving successful implementation of Green manufacturing in any organization. Proper encouragement and rewards for green employees and eager to learn green information. Employees get assessment whenever they are required or occurring problems. (Hsu and Hu 2008).

3. Human Resources Poor Quality

Organization consisting of rich quality of human resources as good training facilities and education system will certainly help in implementing Green Manufacturing practices. Human resources of quality gives new ideas for organizations learn new technologies easily and share knowledge with each other and utilize new technologies to solve problem (Yu Lin and Hui Ho, 2008). As the financial constraints barrier of the organization is Poor Human resource quality.

4. Market uncertainty and competition

Present generation situation market's uncertainty is very higher because of global competitiveness and due to customer's requirement. Benchmarking of global competitors and research will develop and deploy strategies. External environment in which an organization performs its business will also influence the innovative capability as well as intention to adopt innovations (Hosseini, 2007).

5. Lack of implementing Green practices

Green practice innovation lies within the explicitness of green practices, accumulation of green knowledge, quality human resource and company's encouragement. Green practices innovation indulge in hazardous solid waste disposal, energy conservation, recycling and reusing of materials. Innovative green practices promote innovative design, opportunities of new market and makes their quality better than others. However, because of market

competition and cost implications, organizations try to save cost (Ravi and Shankar, 2005).

6. Lack of top management commitment

Commitment of Top management support is vital and useful for environmental practices and has the significance capability to influence, support actual formation and implementation of green initiatives across the organization. Management in the Top provides continuous support for Green manufacturing in the strategic action and plan for the successful implementation of Green practices (Ravi and Shankar 2005).

7. Cost Implications

Generally cost is always considered as the primary measure of performance. Initial requirements and investments of the Green practices or methods are very high such as green manufacturing, green design, green labeling and packing. Involving in environmental management engage with two different type of cost they are direct cost and transaction cost. Both these types of cost consider as the barrier for Green (Al-Khidir and Zailani, 2009).

8. Supplier reluctance to change towards Green practices

Supplier's Strengthen relationship results in lower inventory, costs and more accuracy. Supplier involvement in design process and technology affects overall performance of whole process. Supplier manufacturer relationships are considered most important for developing competitive advantage for the manufacturer. The manufacturers cannot produce green products unless they work together with suppliers. Suppliers need to meet the requirement of buyers to maintain business relationship (Sarkar and Mohapatra, 2006).

9. Unawareness of customer

The Important barrier for any manufacturing organization is that lack of awareness of customers about the advantages of green products. Customer's requirements and desire become most crucial type of external pressure. Customer's awareness means if customer ask for green products then company has to change technology and organization for innovative green products. Awareness of customer plays vital role in implementation of green practice and thus it becomes main barrier (Lamming and Hmapson 1996)

How can the use of E-KPI's contribute to a green manufacturing?

KPIs have special meaning to work place learning by considering organizational strategy, structure, and systems (e.g., job system and reward system). KPI bridges the gap between an organization's mission and vision and its employees' targets (Ran & Wang, 2008). We seek to find out the factors that influences or contributes to the green production system in an organization.

Green manufacturing system can be defined as “A sustainable approach for the designing and engineering activities which are involved in the product development and system operations in order to reduce environmental impacts” (Ahmed M. Dief (2011). It is a problem solving approach and innovative techniques for efficient environmental solutions resulting in cost reduction from reduced work handling, efficient control, and process automation along with other environmental efforts all relates to green manufacturing applications (Bala 2008).

E-KPIs play an important role in achieving the goals of Green Manufacturing by monitoring the performance of the production system. These are main factors of E-KPIs which contributes to the green production,

1. Cost savings and productivity gains

Organization manages to save costs and increase efficiency through managing and bringing down resource use which includes, raw materials and supplies, waste reduction, water and energy use in case of identified cost saving areas. By reducing environment impacts, such as waste to landfill, business can significantly reduce or avoid the cost of compliance altogether.

2. Improved sales

Organization can benefit from improved reputation among their customers by reporting on relevant environment issues. Better reporting improves customer confidence. Informing customers of your efforts to improve your organization's environmental performance can lead to increased confidence in your products and services

3. Preferred supplier status

Large scale organizations increasingly require contractors and suppliers environmental performance information to fulfill the expectations of their own shareholders. Reporting on environmental information can make a more satisfying and attractive supplier comparing to other competitor

4. Increased attractiveness to the investment community

By reporting on environmental issues gives a better indication of what measure does an organization is taking in order to reduce risks and develop opportunities. Investors, financial analysts and broker are taking precaution about the sustainability of business operations.

5. Product and service innovation

Managing and measuring impacts of environmental drives supports innovation in product and service development, which helps to secure new customers and markets or safeguard existing ones.

6. Employee recruitment

A better reporting of an organization's efforts to manage and measure its environmental performance helps to attract high-caliber employees as good environmental reputation and performance can be an important factor in an employee's choice of employer.

7. License to operate

Managing environmental impacts and minimizing the organization's impact on the environment can reduce the exposure to fines. It can improve relations with regulators and helps to ensure that the organization maintains its license to operate by providing assurances about compliance with environmental legislation and conformity with other relevant laws and regulations.

An increasing acknowledgment that good environmental KPI's generally makes good business sense. Industries that measure, generate and manage their environmental performance are well placed to react to factors that will ultimately affect consumer behavior, business decisions and resources, as more and more pressure is applied on these factors the long term risks to business increases. Balanced measures provide insurance of one KPI working against another. The application of E-KPI's will assist an organization to be focused on key areas where performance is critical for achieving the environmental vision, mission and objectives of the organization.

8. CONCLUSION

The primary objective of this thesis is to contribute further understanding and effectiveness of Lean and Green production systems and KPI's (key performance indicators) in manufacturing or production companies. A theoretical frame work is made in such a way that to have a good understanding about the concepts and research work in the relevant area. The empirical study at the company has been done to examine their work practices with lean and green practices in their company and the projects & initiatives. The empirical and theoretical study has primarily focuses on lean & green, the practical difficulties faced by the industries and respective drivers and barriers and use of KPI's for attaining sustainable production.

In order to get real time ongoing process in company, research questions has been formulated with the help of literature survey combined with responses from key personnel, answer has been provided.

1. What are the barriers and drivers in production process in attaining green manufacturing practices?

From the literature studies and empirical findings, many drivers and barriers are considered for practicing sustainability or green manufacturing practices. The most important and influential drivers for attaining green manufacturing practices are legal issues from government, cost, proximity to market/customers, resource depletion. On the other hand there are some barriers that restrict the organization from attaining sustainable practices. Some of these are lack of organizational tools, higher overall cost, training requirements and development of new tools and models.

The most important drivers and barriers that influence the organizations decisions to drive for green manufacturing practice or stay normal are legal issues and gaining market share, higher cost and training and new tool development. All the drivers and barriers affect the organizations performance in one way or another. The advantages and disadvantages must be carefully examined and the decision must be carried out according to firm's musts and wants. For organizations for competing with competitors must strive for attaining sustainability for getting a technical and sociological edge on competitors. But company must also look at the cost (barrier) which makes their product feasible for organization and for customers.

2. Why it is difficult to measure and practice green in today's world?

Practicing green or sustainability in an organization in today's world is difficult as the market change takes place so quickly that the product lags behind against other market products, as green system and products requires technology advancements and time for testing, it becomes costly against other products and swing of market makes the product useless. One of the main reasons for not adopting sustainable production in organizations is lack of encouragement among employees and customer awareness, which plays an important role in not pursuing for sustainable operation in organization.

3. How can the use of Environmental-KPI's contribute to a green production system?

Key Performance Indicators (KPIs) provide management a way to develop a common language around the most important processes within an organization. They also provide a way to develop actionable metrics which connect to the bottom line, regardless of department.

From theoretical and empirical studies it can be seen that E-KPI's help the organization to increase its effectiveness in productivity, sales, community attractiveness and environmental performance. This not only gives a cutting edge over its competitors in new product innovation but also save company revenue through focusing on factors such as recovery of material through recycling, less transportation and waste generation. The case company ABB Ludvika has been utilizing two KPI's but there is a room for utilizing E-KPI's which have been suggested, so that they can contribute to increase the effectiveness of the ongoing sustainable operations of the company

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10.APPENDIX

Interviewers

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Interview Questions

Questions about Lean Manufacturing

1. When did your organization start to introduce Lean principles?
2. Why choose Lean Manufacturing?
3. What do you associate with lean philosophy?
4. What is the targets and vision of Lean?
5. What improvements does Lean manufacturing offers?
6. Is it necessary to hire a consult to implement Lean Manufacturing?
7. What are the lean tools used in your organization?

Questions of Green Manufacturing

1. Have you heard of environment or green version of lean?
2. Does organization has dedicated Green Team?
3. What are the environmental factors does your organization consider in strategic decision?
4. Which type of environmental actions has been undertaken in your organization?
5. Has the Lean implementation resulted in benefits and problems within your organization?

6. Are you concerned about the impact of increasing environmental legislation and targets on your organization?
7. What are the environmental concerns in your organization?

Questions of KPI's and E-KPI's

1. What are the different performance measures within your organization?
2. Significant effect of KPI's and E-KPI's on the organization?
3. How often KPI's and E-KPI's are measured?
4. Is it quantifiable and does performance measure contributes to strategic goals?
5. How do you ensure KPI's and E-KPI's reflecting your organizations vital activities?

Questionnaires Results

Question 1

The respondents results for Question 1 i.e. What is the status of knowledge and implementation of Lean Production System concepts in your company on a scale of 1 to 5 representing very low to very high respectively?

The status of knowledge of green production systems in the companies involved in the survey is show in the following pie chart. **76** percent of the companies have an average knowledge and implementation Lean Production Systems. The overall weighted average score is **3.8** out of **5**.

Question 2

The respondents results for Question 2 i.e. What is the status of knowledge and implementation of Green Production System concepts in your company on a scale of 1 to 5 representing very low to very high respectively?

The status of knowledge of green production systems in the companies involved in the survey is show in the following pie chart. **40** percent of the companies have an average knowledge and implementation Green Production Systems. The overall weighted average score is **2.22** out of **5**.

Question 3

The question is the extent of use of lean tools in the company and which of the tools are used. The following series of tables summarizes the results

What kind of Lean tools does your company use and what is their status of use on a scale of 1 to 5?		
5S		
5	3	20,00%
4	5	50,00%
3	2	30,00%
2	0	0%
1	0	0%
N/A	0	0%
Total	10	3,8
Just-in-Time(JIT)		
5	0	0%
4	4	40,00
3	2	20,00%
2	1	10,00%
1	0	0%
N/A	3	30,00%
Total	10	2,6
Continuous Improvements		
5	0	0%
4	2	20,00%
3	6	60,00%
2	0	0%
1	0	0%
N/A	2	20,00%
Total	10	2,6
TPM		
5	2	20,00%
4	2	20,00%
3	4	40,00%
2	1	10,00%
1	0	0%
N/A	1	10,00%
Total	10	3,3

Table 10 How much of the Lean tools are utilized by company

Question 4

Questionnaire is in which areas does the company focus on to incorporate environmental sustainability. The results are summarized in the following table.

Which area does your company focus on to incorporate environmental sustainability?		
Lean and Green		
5	2	20,00%
4	1	10,00%
3	0	0%
2	4	40,00%
1	1	10,00%
N/A	2	20,00%
Total	10	1,4
Decision Support		
5	1	10,00%
4	1	10,00%
3	3	30,00%
2	3	30,00%
1	1	10,00%
N/A	1	10,00%
Total	10	2,7
Awareness		
5	1	10,00%
4	5	50,00%
3	3	30,00%
2	0	0%
1	0	0%
N/A	1	10,00%
Total	10	3,6
Management and Organization		
5	1	10,00%
4	6	60,00%
3	1	10,00%
2	1	10,00%
1	0	0%
N/A	1	10,00%
Total	10	3,7

Question 5

Does all levels of the organization objectives are relatable to KPI's on scale of 1 to 5 in questionnaire 4. The relatable of KPI's in the companies involved in the survey is show in the following pie chart. **64** percent of the organization objectives are relatable. The overall weighted average score is **3.2** out of **5**.

Questionnaire Format

Here follow the format of the questions that were asked in the online questionnaire.

1. What kind of Lean tools does your company use and what is their status of use on a scale of 1 to 5?

Score	5	4	3	2	1	N/A
JIT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5S	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TPM	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Continuous Improvements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. What is the status of knowledge and implementation of Green and Lean Production System concepts in your company on a scale of 1 to 5 representing very low to very high respectively?

Score	5	4	3	2	1	N/A
Lean Status	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Green Status	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3. Which area does your company focus on to incorporate environmental sustainability?

Score	5	4	3	2	1	N/A
Lean and Green	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Decision Support	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Awareness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Management Organization	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. *What is the status of KPI's by using balance scorecard as the framework?*

Score	5	4	3	2	1	N/A
Status	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. Are KPI's relatable on all levels of the organization objectives?

Score	5	4	3	2	1	N/A
KPI's Relatable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

