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Assessing Sustainability Potential at GKN Aerospace Engine systems

Master's thesis by

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Master of Science Thesis [Production Engineering, MPPEN]

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Abstract

Sustainable world is a dream that every human being wishes to exist. Sustainability has emerged as a hot topic due to increased public awareness and governmental pressure, companies need to not only react but also be proactive to sustainability issues. While industrial society is growing, companies face challenges concerning the three pillars of sustainability namely environmental, social and economic. The meaning of each dimension of sustainability is explained as follows; Global warming consequences have strengthened the importance of the environmental dimension and it is perceived as sustainability by major part of society. Economic dimension relates to monetary values, which in the end decide how successful the company is. The social dimension refers to societal (stakeholders) impacts through activities of organisation. GKN Aerospace is one of these companies that know sustainability is important and hence the company is investigating their potential for sustainable development to contribute to a well-being of society and related development.

This thesis work aims to assess the current level of sustainable development and study the requirements in GKN Aerospace engine systems with respect to the three values of sustainability and to provide guidelines that can support the company in their sustainability progress. In order to achieve this, interviews with key stakeholders were performed to understand the company's idea about sustainability and identify departmental level sustainability initiatives and goals. To clarify GKN´s position in relation to other companies, benchmarking has been carried out. Moreover, concept maps were performed to analyse employees' knowledge to relate all three dimensions of sustainability. Further, the company´s production of LPT (Low Pressure Turbine) case´s has been evaluated based on criteria matrix in cooperation with GKN´s research and product development department. The results and analysis shows that the company has taken valuable initiatives and efforts towards sustainable development; however this has not yet been realized to full extent and it could be achieved through improving organisation's long term focus and strategy, knowledge transfer from all levels and effective internal and external communication. Based on these conclusions, organised nine step guidelines were derived to aid the company to close the gaps and initiate with the process of sustainable development.

Keywords: Sustainability, Potential, Sustainable Development, Assessment.

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Daniel Strömberg & Thulasi Ramachandran
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List of Acronyms

LPT case: Low Pressure Turbine case

OEM: Original Equipment Manufacturer

REACH: Registration, Evaluation, Authorisation and Restriction of Chemicals

SIN: Substitute It Now

1 Introduction

Sustainable world is a dream that every human being wishes to exist. But the challenges and pressure towards sustainable world are increasing day by day. Sustainability is a concept of focus in all business sectors as they are major part in contributing to impacts regarding sustainable world. Hence in today's world, manufacturing business sectors are driven by sustainability challenges. Sustainability has three main facets namely ecological, social and economic. Therefore, sustainability approaches should be an integration of all three facets. The meaning of each dimension of sustainability is explained as follows; Global warming consequences have strengthened the importance of the environmental dimension and it is perceived as sustainability by major part of society. Economic dimension relates to monetary values which in the end decide how successful the company is. The social dimension refers to societal (stakeholders) impacts through activities of organisation. GKN aerospace is one of these companies that know sustainability is important and hence the company is investigating their contribution to a better society in terms of sustainable development. Also, increased competitiveness on the market pressures the company to fulfil and exceed customer expectations in every day practice, and at the same time make strategic decisions for long term success.

The level of compliance with sustainable development depends on the company´s vision and objectives and in this thesis work four drivers for sustainable development are pointed out. Figure 1.1 presents these drivers that will be mentioned frequently in this thesis work. To meet changing market conditions due to regulatory changes and also manage increased public awareness about sustainability, increased focus on the environmental and social aspects need to be taken into account to ensure economic value in the future. Hence, sustainability management is an on-going process and establishment of a sustainability approach concerning strategy and goals on an overall level have to be supported by metrics and relevant indicators on operational levels to maximize the company´s sustainability efforts.

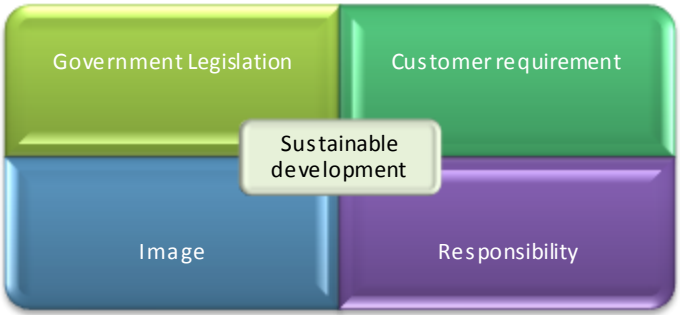

Figure 1.1: Drivers for sustainable development in the company

1.1 About the Company

GKN PLC is a global engineering group established in 1759 delivering technology and products for vehicles and aircrafts. GKN PLC has four divisions namely GKN driveline, Aerospace, Powder Metallurgy and Land systems. GKN aerospace is a leading manufacturer of airframe and engine structures, components, assemblies and transparencies to a wide range of aircraft and engine prime contractors and other first tier suppliers. It operates in three main product areas: aero structures, engine components/sub-systems and special products. GKN Aerospace Engine Systems (hereafter mentioned as GKN/GKN Aerospace) with headquarters in Trollhättan (Sweden) develops designs and

manufactures advanced high precision components for commercial and military aircraft engines, space rockets and industrial gas turbines.

Regarding sustainability and its related development in GKN, the company is a part of the aerospace initiatives to contribute to the overall aerospace goals of reducing the carbon emissions from Air transport by 50% in 2020 (International Air Transport Association airport, 2014). And also, there are ongoing sustainability efforts in product development through collaboration with universities.

1.2 Low pressure turbine case

GKN manufacture Low Pressure Turbine case (hereafter mentioned as LPT case) which is used as case study in this thesis work. Trollhättan site performs the final machining processes and quality inspection before delivering to the customers. The potential customers include GE and MTU. The increasing competition of LPT case has created a pressure in GKN to increase the market and hence to increase the number of orders from customers.

This product will be used to evaluate and study the sustainability potential of LPT case production and to an extent product level. These theses serves as identifying sustainability values for the LPT case production and hence give support for sustainable development of GKN on an operational level as well.

1.3 Project Background

The company is exploring a sustainable development approach in order to meet customer and legislative requirement on sustainability issues. In addition, there is increased market interest in broader aspects of sustainability. For instance, fuel efficiency and product weight have always been important environmental aspects in the aerospace industry, but now aspects as noise and material content are getting higher influence on product and production development. Furthermore, the company recognizes the need to understand the next generation products and production processes to enable better offers to customers in the future. Especially, attention has been paid to the LPT case products that are very costly to produce due to current technology used. Therefore there is a need for GKN to investigate whether their processes and products could be improved with respect to the triple bottom line. As a first step, the meaning of sustainability has to be explored taking all dimensions of sustainability into account in order to identify gaps in the organization, which are barriers for sustainable development. Accordingly, their sustainability potential could be assessed and strategies could be established to improve their capabilities through judging their current level of sustainability performance and so their adaption to market changes over time. This thesis work aims to evaluate the product and production sustainability requirements for LPT case.

Implementation of sustainability is different from implementing other policies in an organization, since it is mostly based on long-term goals and the direct link to profit is usually not that clear as immediate operation goals. For sustainability, however, the goal is to achieve excellence in social, environmental, and financial performance simultaneously (Mirvis, et al., 2010). This is an on-going progress that is mostly referred as sustainable development and understanding about this is important while working towards sustainable manufacturing, in order to evaluate new technology, product and process modifications and to identify sustainable values in their value chain. Lastly, in a business point of view, it is essential to achieve a deeper understanding how the next generation programs are related to sustainability and the four drivers stated in Figure 1.1, in order to generate more attractive offers and at the same time achieve more efficient operations.

1.4 Problem description

Sustainability has come into light in GKN Aerospace as a result of external drivers like: changing market trends, societal importance, sustainability definitions, competitors and environment regulations and external organizations' legislations like ACARE (Innovation & Advisory Council for Aviation Research and Innovat, 2014), REACH (European chemical agency, 2013), ICAO (International Civil Aviation Organization, 2014), IATA (International Air Transport Association, 2014), IAEG (Environmental Industry Aerospace Groups, 2014). As a result, GKN Aerospace has developed the six ways of living out of which two are related to sustainability. In future, GKN might need to provide their customers with data regarding material waste; material substances; energy consumption, CO_2 Emissions etc., and therefore they need to find a smart sustainable approach in terms of a strategy supporting flexibility considering these changing conditions and trends towards a sustainable future. Hence, it is important for GKN to be proactive and take steps towards sustainable development. At this stage, it is important to understand GKN's knowledge about sustainability values and their level of sustainability efforts. This will help to initiate with required efforts to lead in the path of sustainable development. This stage is crucial and should be handled very strategically as this defines the future of GKN.

1.5 Purpose

The purpose of this thesis work is to support GKN in the process of sustainable development through analysing the current state in GKN and evaluating production and product sustainability potential of LPT case.

1.6 Goals

This thesis work will focus on studying the level of GKN's knowledge and efforts for sustainability. The product LPT case' product design and its production system will be used as an example. This product will be evaluated to identify sustainability issues and appreciate the importance of sustainable processes. This thesis work also includes indicating the steps to be taken by GKN that will lead the company in their sustainability progress.

The goal of this thesis work includes:

1. Literature studies in the area of sustainable manufacturing and sustainable product development to identify relevant theory and approaches to GKN products and production.
2. To study about current state of sustainability in GKN by:
   - Identifying GKN's stakeholders for sustainability and perform studies to understand the knowledge level about sustainability values.
   - Performing benchmark to compare GKN's efforts and find out relevant information about progress and possible future trends and market conditions within aerospace.
3. Make a case study of a LPT case product line and its production system to:
   - Evaluate LPT case using sustainability criteria matrix to understand the issues regarding sustainability.
   - Suggest possible improvements with respect to sustainability
4. Develop Guidelines for Sustainable development of GKN.

1.7 Delimitations

The thesis will be conducted for GKN aerospace engine system site in Trollhättan. It is limited to identifying and assessing improvements for production and related processes of LPT case in Trollhättan site only. Also the time period of study is limited to 5 months and the result should be seen as an indicative measure of the current state based on the LPT case production.

1.8 Precision of research questions

1. Where are the current gaps in following sustainability approach for GKN?
2. What are the possible and successful steps for sustainable development of GKN?

1.9 Value of our Thesis work to GKN

The results and deliverables of this thesis work can contribute to the following:

- Support GKN in their sustainability implementation and development
- Identify current gaps
- Identify important steps
- Support to GKN´s research department

1.10 Thesis Outline

Thesis work covers the following chapters in this report,
Chapter 1: Introduction – Project background, its purpose and objectives and the research questions are presented.
Chapter 2: Literature review – Provides a framework of understanding for the thesis work by presenting literature on sustainable manufacturing and related work.
Chapter 3: Methodology – Description of tools and methods used for performing the thesis work.
Chapter 4: Results – Presentation of results obtained from using the methods and tools.
Chapter 5: Analysis & Discussion –Presentation of the correlation of literature findings and results.
Chapter 6: Sustainability Indicators Framework - Explains the purpose of sustainability indicators and presents a model of indicators.
Chapter 7: Guidelines for Sustainable development of GKN – Description of steps for sustainable development in GKN.
Chapter 8: Conclusion– Conclusion of the findings and Future research suggestions.
Chapter 9: References & Bibliography.

2 Literature Studies

A literature review is made to give the reader an understanding about current research about sustainability for manufacturing companies. Literature studies are formulated in this chapter as following; firstly, an overall understanding about the meaning of sustainability as a concept is presented and then the aerospace industry is discussed followed by emphasizing the importance of sustainability strategy and barriers for environmental practices and approaches. Further, current research ideas in sustainable supply chain management and related technology is provided and completing with brief explanation about sustainability assessment, indicators and reporting. The theory discussed is linked to the different aspects of sustainability that has been identified as relevant according to result achieved from stakeholder interviews, concept maps and benchmarking. Moreover this theoretical framework has the purpose to identify sustainability values for manufacturing organizations and provide theory for the research questions:

1. Where are the current gaps in following sustainability approach for GKN?
2. What are the possible and successful steps for sustainable development of GKN?

2.1 Introduction to sustainability

While awareness in public has increased, companies have understood the need of integrating sustainability into their core business. When Lean production started as a philosophy for industrial companies to increase competitiveness by reducing waste etc., sustainable production is extended to also focusing on energy consumption and life cycle assessments considering activities outside the company´s boundaries as well. As public awareness has increased about environmental issues, industrial companies are pressured to contribute with less environmental impact and to exhibit environmental practices. For this reason, actions are taken by manufacturing companies to integrate sustainability into the company´s core business. Equally, as Toyota is a good example of Lean production, there are companies that are leader in sustainable development.

Most authors and researchers agree that there are three aspects of sustainability namely Social, Environmental and Economic, also known as Planet, Profit and People (Fisk, 2010). Also, it is commonly expressed as Triple Bottom Line of sustainability. According to United Nations World Commissions on environment and development, sustainability is defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). The concept of sustainable development got increased focus in the early and middle of 1980´s as an attempt to overcome the gap between environmental concerns about the increasingly evident ecological consequences of human activities, and socio-political concerns about human development issues (Robinson, 2004). Because of these growing concerns, business enterprises are under strong pressure to measure their impacts on the environment and to engage in triple bottom line reporting to account for the energy and other resources they use and the resulting footprint they leave behind (Kleindorfer, et al., 2005). Furthermore, Kleindorfer, et al. (2005) claim that the primary activities that contribute to a company´s footprint are producing and transporting current products, recycling, remanufacturing, and reusing used products and designing new products. Thus, in a manufacturing environment, sustainable production could be defined as “creation of goods and services using processes and systems that are non-polluting, conserving of energy and natural resources, economically efficient, safe and healthful for workers, communities, and consumers, and socially and creatively rewarding for all working people” (Lowell University of Massachusetts, 1996).

In relation to manage also social and environmental aspect in higher extent, Fisk (2010) means that if there is a genuinely reason why the organization exists beyond making money, then everyone stops striving to optimize revenues but also see revenue in social and environmental efforts. Figure 2.1 presents the three pillars of sustainability and illustrate that sustainability is lying in the intersection phase of these pillars (Lynch-Caris & Lynch, 2010).

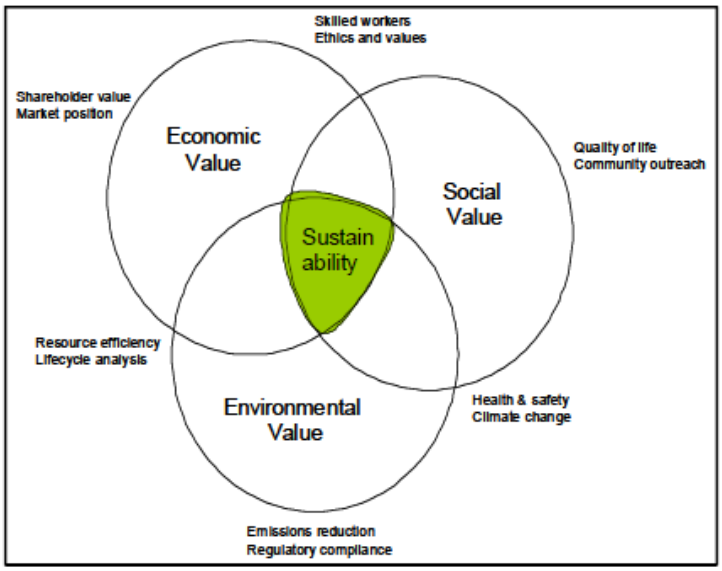

Figure 2.1: Triple bottom line of sustainability (Lynch-Caris & Lynch, 2010).

Sustainable development lead to lot of changes in the process and operations of company and it has potential advantages as well. Through sustainable development, every company could gain the following, according to Strandberg Consulting (2009):

1. Improved brand image
2. Competitive advantage
3. Financial savings
4. Improved Employee motivation
5. New markets
6. Improved supply chain management

Sustainable development requires an ongoing process of planning, management, evaluation, adaptation and accountability, based on a regular flow of information (Dalal-Clayton, et al., 2002). Many tools and techniques are developed for sustainable development of companies. Hallstedt (2014) defines sustainability criteria and sustainability compliance index for decision-making in product development. Furthermore, Hallstedt (2014) discusses sustainable development in terms of strategic sustainable development in a life cycle perspective. For a company is it important to have understanding about e.g. sustainability implications of the materials and chemicals currently used, the sustainability implications of the manufacturing processes used, improved working environment in the manufacturing site, a product design that allow for recycling and materials in closed- loops within value chain (Hallstedt, 2014).

2.2 Aerospace industry

The aerospace industry distinguishes from e.g. vehicle industry concerning aspects as production volume, production flow and quality requirement and business model. In aerospace industry, quality

is one of the critical concerns due to reason it is more complex and long working life of the aerospace products. Haque (2003) discusses lean engineering in the aerospace industry and mean that lean manufacturing is not only well established in the automotive industry where it originated, lean thinking has spread to other sectors. Also, concept as Just in time and 5S are essentials in the aerospace industry. King, et al. (2007) specially point out technology uncertainty as one of the issues within the aerospace industry and also claims that in the aerospace sector, most firms are committed to make large investments in research and development for strategic purposes in order to reduce environmental impact, reduce lead-times and so improve production flow. However, according to this author technological advances are also related to risks. Also, as a cyclical industry with unpredictable commercial cycles, many factors influence the pattern of new aircraft orders (Bramham, et al., 2004). Consequently, high level of technology and uncertain markets, companies within the aerospace industry are forced to deliver high quality in time and introduce cost reduction programs and establish strategies to manage increased governmental pressure regarding legislation and increased requirement from customers concerning environmental issues.

2.3 Sustainability strategy

Sustainability mission for an organization is to do business (economic dimension) and at the same time, take environmental and social aspects into account. Thus, companies are searching for their sustainability values, which is about searching for future values for the company. Accordingly, Bocken, et al. (2012) mean that business model innovations for sustainability may not be economically feasible in the beginning but may become so in the future due to regulatory changes and customer needs. Moreover, this part of literature studies aims to highlight how sustainable strategies are discussed in literature. Also, discuss why a strategy is important for sustainable development. For companies' competitiveness, a strategy is important since it describes how the company reach their goals. In this chapter, business strategy and environmental performance are discussed to discover how environmental performance is related to economic value. In some countries, as Denmark, Germany, Norway, Sweden and in high environmental risk industries like the chemical industry, automotive and heavy engineering, managers consider improvements in environmental performance one of the basic competitive priorities, alongside lower cost and production lead time or higher quality (Azzone & Noci, 1998). Furthermore, Azzone and Noci (1998) clarify the meaning of environmental improvements claiming that it may require modifications in product structure i.e. new materials and regarding production, improvements of technology towards "cleaner technologies", e.g. technologies that cause fewer spills of substances and material waste and emissions from the factory. In this context strategy is an important aspect for companies to support balancing the three dimensions of sustainability namely environmental, social and economic. As discussed, industrial organizations have understood the importance of integrating strategy in their business, and the following points describe how companies have considered sustainability in their business model regarding sustainability reporting and its future (Campbell, et al., 2012):

1. Most firms have changed or modified firm strategy in response to sustainability initiatives.
2. Many firms are including sustainability analyses in capital investment decisions.
3. Disclosure and transparency pressure from outside groups has increased (e.g., nongovernmental organizations, customers, environmental groups, and regulators). In addition, recent research suggests that sustainability disclosures result in beneficial firm outcomes.
4. Sustainability reporting in annual reports and other filings has increased substantially.
5. Many investment firms are using sustainability as an investment criterion, especially those firms and funds that focus on socially responsible investing.

Campbell, et al. (2012) claim that finance function should take a stronger supporting and often a leading role in sustainability. Additionally, this author presents a model including four aspects with associated criteria for evaluating the organization´s maturity level regarding their sustainability strategy which is presented in Table 2.1.

For instance, the authors explain that a function with an antagonistic attitude toward sustainability, would criticize the validity of sustainability measures and the value of sustainability reporting, and have a negative attitude regarding alignment of sustainability and corporate strategy. Hence for different aspects, different maturity levels are defined to clarify the degree of sustainability implementation for an organization concerning integration of sustainability into strategy. Campbell, et al. (2012) mean that organizations have to adapt to increasing pressure from stakeholders and market expectations about sustainability management. Further this author argues that organizations that fail to meet such expectations will face negative reactions in capital market, and the author especially points out the finance function as responsible for performance measurement and strategic planning to lead and support the organization's integration of sustainability efforts.

Table 2.1: Criteria for evaluating the organization´s maturity level (Campbell, et al., 2012)

	Antagonistic	*Agnostic*	*Supportive*	*Proactive*
Alignment of Sustainability With Corporate Strategy	Actively works to exclude sustainability from strategic discussions and initiatives	Passively accepts, but does not approve, sustainability as part of corporate strategy	Accepts and approves explicit statements about sustainability in the corporate strategy	Encourages, drafts, and promotes explicit statements and emphasis on sustainability in the corporate strategy.
Integration of Sustainability Measurement and Reporting With Existing Systems	Openly criticizes the validity of sustainability measures and the value of sustainability reporting	Does not contribute to, but does not impede, others' development of sustainability measures and reports	Supports requests for aid in sustainability measurement and stand-alone reporting with resources and expertise	Leads the development of valid sustainability measures; creates clear causal links between sustainability measures and strategic goals.
Connection of Sustainability Outcomes to Long-Run Financial Performance	Disputes the financial value of sustainability initiatives and reporting, and works against their inclusion in measurement systems; champions short-term financial trade-offs	Neither approves nor disapproves of claims of connection between sustain-ability outcomes and financial performance; emphasizes short-term financial trade-offs	Accepts demonstrated connections between sustainability outcomes and long-run financial performance but may continue to emphasize short-term financial trade-offs	Champions clear data-driven relationships between sustainability outcomes and long-run financial performance; emphasizes long-run outcomes over short-term financial trade-offs
Development and Management of Sustainability-	Argues against the potential for intangible benefits/	Remains passive when potential intangible benefits/assets	Develops valid measures for and clear reports about intangible	Develops valid measures for intangible benefits/assets

Related Intangible Assets	assets due to low validity of measurement.	are discussed	assets/benefits when requested, and supports their stand-alone communication	and their connection to long-run financial performance.
Enhancement of Risk-Management Portfolio Through Sustainability Initiatives	Refuses to consider sustainability as part of the risk-management portfolio	Allows stand-alone claims of risk-management benefits from sustainability initiatives	Supports risk-management benefits of sustainability initiatives when communicated through stand-alone reports	Promotes risk-management benefits of sustainability initiatives and integrates them into regular discussions of risk-management portfolio

In a similar manner, Jefferson, et al. (2014) discuss the maturity levels of sustainability in product development and this is presented in Table 2.2.

Table 2.2: Maturity level of sustainability in product development (E. Jefferson, et al., 2014)

S. No	Maturity level	Primary Focus
1	*Beginning*	Regulatory compliance
2	*Improving*	Sustainability considered in production development, for suppliers, and in reporting metrics
3	*Succeeding*	Sustainability included throughout much of the enterprise, including production development, marketing, public metrics, reporting, and used as a competitive advantage in some markets
4	*Leading*	Sustainability fully integrated throughout enterprise, viewed not as an initiative, but rather as the way the company does business

Also, Jefferson, et al. (2014) state that sustainability must be linked to the business metrics since that is the only thing executives and shareholders care about. Consequently, this author claims that companies need clear and relevant metrics to track their implementation progress. The study presented in this article shows that companies adopt different metrics based on their particular needs. Although companies should spend some time developing a strategy of implementing sustainable practices, and then adopt those metrics that best support their strategy (Jefferson, et al., 2014).

In addition to stakeholders´ interest, Chai (2009) discusses business scorecard and present four perspectives of how a company could be reviewed and they are as follows:

- **Financial perspective**: because the final objective of an enterprise operation is to make profit for shareholders, the BSC retains an emphasis on achieving financial objectives.
- **Customer perspective**: the loyalty of the customer to their suppliers is so critical that "customer satisfaction" becomes one of the core outcome measures and long-term strategy.
- **Internal process perspective**: in this perspective, executives will identify the key processes in which an organization must excel to meet the above objectives.
- **Learning and growth perspective**: to face the serious change of competition environment and meet the long-term goals, the companies should continually improve their capabilities to achieve the internal process improvements, customer satisfaction, and ultimately financial success.

Balance scorecard could be used to investigate the impact sustainability implementation has on the company. Thus, balance scorecard may be a good way to relate to sustainable development. However, Azzone and Noci (1998) claim that a company´s strategic attitude depends on manager's environmental awareness. For instance, the reduction of the company's impact on the environment is more important than economic performance for some managers, while there are other managers that consider environmental performance as business advantages as green product development adds value to the customers. In addition, these authors mean that there are managers that only focus on compliance with laws and regulations or have a very positive attitude to lead environmental performance. Lastly, Azzone and Noci (1998) mention that there may be managers that hinders the company´s sustainability efforts due to short term thinking.

But high-level managers have become aware that a long-term viewpoint is necessary for dealing with environmental issues (Hsu & Liu, 2010). Hsu and Liu (2010) mean that balanced scorecard provides management with an effective control tool for proactive environmental strategy realization.

Furthermore, the authors present four perspective of measuring performance which is presented in Table 2.3. Balance business scorecard evaluates the organization´s learning progress towards long term goals considering financial results, customer value and environmental performance.

Table 2.3: Different perspective to review the company´s environmental performance (Hsu & Liu, 2010).

Perspective	**Measures**
Financial perspective	Cost of pollution treatment
	Cost of cleaner production
	Cost of research and development
	Investment for environmental improvements
	Revenue of greener products
	Profit from recycle and resource consumption reduction
	Return on environmental

	investment
Customer perspective	Customer satisfaction
	Quality improvement due to greener products
	Quick response to environmental issues
	Report env. Progress to shareholders
	Good relation with community
	ISO 14001
	Environmental protection award
	Green image and information disclosure
Internal perspective	Innovation on products and technology
	Green design
	Continuous monitoring
	Clear goal for greener products
	Green purchasing
	Cleaner production
	Process efficiency
	Standard for chemicals and other raw materials
	Cleaner working environment
	Customer satisfaction surveyed regularly
	Supplier side management
	Pollution control and treatment
Learning and growth perspective	Environmental education and training
	Skill, ability and knowledge
	R&D ability and experience
	Employee satisfaction
	Employee initiative
	Employee commitment and cooperation
	Understanding to related policy and laws
	Acquisition of environmental information

2.4 Environmental practices and approaches

Hajmohammad, et al. (2013) define environmental practices as "The level of resources invested in activities and know-how development that lead to pollution reduction at the source". It includes efforts to implement environmental management systems, reduce waste, or recycle materials. According to Hajmohammad, et al. (2013), companies that focus on waste reduction to reduce cost also increase their environmental performance. Further, this author means that that lean management and supply management are important determinants of environmental performance and can be seen as capabilities that ease the adoption of environmental practices. Additionally, Hajmohammad, et al. (2013) discuss how practices as supply chain management and Lean production are connected to sustainable production. To clarify, production philosophies are developing, from focus on economic waste increasingly consideration is taking to environment and society and lead to sustainable production. Also, the authors examine whether the adoption of lean and supply chain management practices within the organization improves its environmental performance. The implementation of environmental management practices and the development of eco-products are popular approaches for manufacturers to reduce the environmental damage from production processes and subsequent consumption by customers (Atasu, et al., 2008). In addition to eco- products, Seliger, et al. (2008) mean the scientific approaches has increased focus on design and recycling of material and components compared to earlier efforts made to focus more on reducing environmental impact during usage phase. Seliger, et al. (2008) present three important strategies towards a sustainable manufacturing approach to increase use-productivity in the total product life cycle:

- *Implementation of Innovative Technologies* is a strategy focusing on the evaluation and implementation of feasible and innovative technologies for resource-saving applications.
- *Improving the Use-Intensity* is a strategy to improve use-productivity by increasing the utilization ratio of a product. This strategy intends to maximize productivity per resource input.
- *Extension of Product Life Span* is a strategy focusing on extending the time between cradle and grave of a product by expanding the use phase and realizing multiple use phases. The resource consumption for production and disposal of products shall be reduced with this strategy.

In addition, the author refers to Caterpillar as a good example of a sustainable approach and explain that the Caterpillar remanufacturing service has 12 remanufacturing factories all over the world, and their remanufacturing process saves 85% of the energy in comparison with original production, and 25% of the remaining material is recycled. In relation to these practices Caterpillar has achieved a sustainable approach by integrating sustainability values into business objectives and strategies.

According to Seliger, et al. (2008), allowing multiple use phases of products and components extension of product life span can be realized. Also this author states that the environmental impacts caused by production and disposal can be reduced, while the remarketing of remanufactured and adapted products can be profitable business fields. Lastly, the authors also claim that for efficient remanufacturing and adaptation processes, products have to be designed considering the whole life cycle, starting from the development along their use up to their reuse or disposal.

Moreover, Wong, et al. (2014) examine the value of green advertising in sharing and publicizing information about organizational achievements in environmental preservation in a business context.

Wong, et al. (2014) mean that, by sharing relevant environmental information, for instance communication about new environmental initiatives, the company can influence customers' judgments and their opinions about a manufacturer. Regarding sustainability profile/ marketing, Wong, et al. (2014) discuss green advertisement as a competitive advantage.

2.5 Barriers for environmental implementation

In this literature review, drivers for sustainability have been discussed as regulations, customer awareness about their supplier's environmental performance; however there are also barriers that hinder organizations from going green. In other words economic is prioritized and green practices are seen as internal costs rather than value for customers. Mathiyazhagan, et al. (2012) claim that industrial organizations sometimes feel that they cannot gain competitive advantage by adopting environmental practice as it is perceived as cost.

Organizational barriers for environmental implementation are presented below according to Mathiyazhagan, et al. (2012):

1. Inadequate top management leadership
2. Low awareness level about sustainability
3. Poor communication
4. Lack of support and guidance
5. Negative attitudes and unfavourable firm culture
6. Uncertainty about the potential environmental and economic benefits resulting from the implementation of clean practices
7. Sustainability principles and rationale are little understood or appreciated below senior management levels;
8. The ideals often do not become translated into everyday practices, lacking genuine support from senior management, infrastructure, strategies, or consistency with core operational practices and reward systems; or
9. The practices are perceived too costly, difficult, time-consuming, or removed from core business goals to be worthwhile.
10. Employee attitude

These barriers are considered as bottlenecks for sustainability implementation.

2.6 Sustainability and supply chain management

Sustainable supply chain management is the management of material and information flows as well as cooperation among companies along the supply chain while taking goals from all dimensions of sustainable development, i.e. economic, environmental and social, and stakeholder's requirement into account (Stefan, et al., 2008). According to Hajmohammad, et al. (2013) supply chain management can ease the adoption of green technologies or implementation of new green procedures as supplier's knowledge becomes accessible to the buying organization.

As a consequence, manufacturing organizations needs criteria for sustainability assessment and to understand how the company can influence their impact considering the whole supply chain. For the reason that focus on environmental management and operations has moved from local optimization of environmental factors to consideration of the entire supply chain during the production, consumption, customer service and post-disposal disposition of products, sustainability stretches the concept of

supply chain management to look at optimizing operations from a broader perspective (Vaidyanathan, et al., 2007). Vaidyanathan, et al. (2007) mean that current legislation, public interest and competitive opportunities are concerns that companies today are facing. Additionally, the authors highlight challenges such as product design, by-products management, product life extension and recovery processes at a product's end-of-life and mean that this has to be integrated in supply chain management environment.

Gopalakrishnan, et al. (2012) performed study on British Aerospace systems and present a framework of the ten essentialities for deploying sustainability in supply chains:

1. Supplier management and integration of supply chain
2. Methods to reduce costs through period–cost analysis
3. Quality and safety system protocol
4. Carbon management across supply chain
5. Review sourcing of raw materials ensuring sustainable procurement
6. Government legislations and external support factors
7. Department ensuring social, economic and environmental considerations
8. Organisational culture and employee involvement
9. Product reuse and recycle specification
10. Key performance indicators (KPIs) of sustainability initiatives

These essentialities highlight the key factors to focus in supply chain sustainability of aerospace industry and it could provide advantages if they are taken into account.

2.7 Sustainable Technology

While market pressure put higher demand on environmental performance on industrial companies, there is a need for innovations that support industry to manage increased requirement. There is need for technologies that help companies reduce their environmental impact and creates new possibilities. One of them is additive manufacturing that presents a number of opportunities in terms of design freedom, minimized waste and ease repair of products (Olaf, et al., 2010). Moreover, Olaf, et al. (2010) state that sustainability is rapidly emerging as an issue that designers and engineers must engage to survive in a more sustainability conscious world. In addition, the authors discuss "triple bottom line" solutions and mean that an ideal product is one which maximizes all three areas in that it is good for the environment, is profitable for the company and improves society.

Much of the literature presented in this thesis work have mentioned sustainability values as waste reduction and less emission, nevertheless design is also an important factor to consider while extended life of a product reduce the environmental impact. Accordingly, technologies that contribute to environmental design to feasible cost and are socially acceptable are identified as innovative technologies with respect to the three values of sustainability. According to Olaf, et al. (2010), additive manufacturing has great potential as an effective tool for more sustainable product design. Additive manufacturing typically also does not require the large amounts of time needed to remove unwanted material, consequently reducing time and costs, and producing very little waste (Wohlers, 2009).

2.8 Sustainability Assessment

In general, companies know sustainability is important but for manufacturing companies, managers need support in evaluating the interrelation between all aspects of sustainability.

Sustainability assessment is viewed as an important tool in helping the companies in the process of shift towards sustainable development. Popea, et al. (2004) define sustainability assessment as a process by which the implications of an initiative on sustainability are evaluated, where the initiative can be a proposed or existing policy, plan, programme, and project, piece of legislation, and a current practice or activity. The aim of sustainability assessment is to ensure that ‘‘plans and activities make an optimal contribution to sustainable development’’ (Verheem & Tonk, 2000).

Sustainability assessment should be able to cover all the three pillars of sustainability namely environmental, economic and social. Most of the literature point out the environmental impacts as the heart of sustainability assessment and very less focus on social and economic. Integrating environmental considerations while taking decisions could contribute effectively to sustainability assessment. Extension of the environmental criteria into social and economical is important to integrate and balance all the dimensions of sustainability. To perform this, there is a mandatory requirement for strategy and policies supporting the sustainability assessment and vice versa.

In an article about sustainability assessment (Popea, et al., 2004), sustainability assessment is viewed as a tool in the ‘family’ of impact assessment processes, closely related to Environmental Impact Assessment (EIA) applied to projects and Strategic Environmental Assessment (SEA) applied to policies, plans and programmes. The article also emphasizes the importance of integrated assessments by analysing various conceptualizations of sustainability assessment namely:

1) EIA-driven integrated assessment
2) Objectives led integrated assessment
3) Assessment for sustainability

Figure 2.2 shows the comparison of three conceptions of sustainability assessment. They conclude that sustainability assessment should assess if an initiative is sustainable, and not simply assess ‘direction to target’. And also, TBL (Triple Bottom Line) view of sustainability could theoretically be used as a starting point to develop these criteria, which in reality is unlikely to be successful, and principles-based approaches are recommended.

Comparison of three conceptualisations of sustainability assessment

	EIA-driven integrated assessment	Objectives-led integrated assessment	Assessment for sustainability
Origins	Ex-post, project-based EIA.	Ex-ante, objectives-led strategic environmental assessment.	Recently defined in theory, but not yet evident in practice.
Aims	To identify the environment, social and economic impacts of a proposal after a proposal has been designed, and compare these impacts with baseline conditions to determine whether or not they are acceptable.	To determine the extent to which a proposal contributes to defined environmental, social, and economic goals, before a proposal has been designed and to determine the 'best' available option in terms of meeting these goals.	To determine whether or not an initiative is actually sustainable.
Contribution to sustainability	Reflects a 'three-pillar' or TBL approach. Aims to ensure that impacts are not unacceptably negative in any of the three pillar-categories.	Reflects vision of sustainability as a series of societal goals and measures contribution to goals. Asks whether things can get better, rather than just whether they can be prevented from getting worse.	Allows society to define what is meant by 'sustainability', and then to compare initiatives against this definition.
Treatment of impacts	Minimise negative TBL outcomes.	Maximise positive TBL outcomes.	Starts not from a 'trade-off' perspective between impacts, but from the idea that 'sustainability' may be more than the sum of parts.
Relation to 'target'	Direction to target.	Direction to target.	Distance from target.
Limitations	Most likely to result in 'weak sustainability' and trade-offs between categories.	Do TBL objectives really reflect sustainability?	Deciding upon a clear concept of what is meant by 'sustainability', and defining criteria

Figure 2.2: Principle based sustainability assessment which includes criteria related to all dimensions of sustainability, (Popea, et al., 2004)

In general, the environmental and social scarcities are only partially reflected in the economic transactions and sometimes managed by means of specific environmental or social management systems not linked to the economic success of the firm. Thus, the contribution of the environmental and social management remains unclear (Raúl, et al., 2009). An evaluating system in this thesis work aims to clarify the values within all dimensions of sustainability, e.g. if two alternative solutions are compared then the evaluation system should be able to point out the different values for each solution in aspects related to operations, tactical approach and if these values are aligned with the overall strategy of the company.

''Sustainability assessment tool that can help decision-makers and policy-makers decide what actions they should take and should not take in an attempt to make society more sustainable'' (Devuyst, 2001).

The literature reflects Environmental Impact Assessment (EIA) and Life Cycle Assessment (LCA) as tools to map the environmental impact of different products. However, these assessment tools are time consuming and require a lot of data. There is a demand from managers to have more decision support regarding sustainability considerations on a daily basis. For instance if several concepts are evaluated with respect to sustainability, which values determine the best concept. In this case it is essential to have some kind of evaluating system that relates to the strategy of the company, goals and policy. Values could be another technology that results in less waste e.g. additive manufacturing where instead of taking away a lot of material, material is added to create a specific shape, also modular design concepts are widely discussed in aerospace industry to reduce the scarp rate and parts and ease repair. But also the social and economic dimension needs to be taken into account.

2.9 Sustainability Indicators

As mentioned by Veleva, et al. (2001), indicators are typically numerical measures that provide key information about a physical, social or economic system. Indicators have three key objectives:

1. To raise awareness and understanding;
2. To inform decision-making; and
3. To measure progress toward established goals.

Olsthoorn, et al. (2001) present the implication of environmental indicators among different levels of managers. Figure 2.3 represents the significance of indicators and it serve as measure of organization progress.

Different users and functions of environmental indicators inside and outside the firm

User/decision context	Function for the user
Corporate manager	To monitor a firm's "environmental" development in relation to strategic targets (derived from concern about future impacts of environmental developments) To identify most harmful wastes and emissions [38] To communicate corporate environmental performance/attitude to stakeholders (shareholders, environmental authorities, clients) Reference performance in preceding periods/years
Production plant manager	To identify opportunities for improvements of efficiency To convey information on the efforts to limit environmental impact of plant operations
Market manager	To identify new market opportunities To defend market positions; reference point competitors
Purchasing manager	Accountability; business-to-business relations
Environmental authorities (compliance situation)	To test compliance of firm with permits
Authorities (national)	In voluntary agreements; communicating a firm's effort to environmental improvement Useful for constructing databases that are helpful in developing and implementing a government's environmental policy
Investors and shareholders	Indicator for financial performance May indicate environmental liabilities that could affect a firm's financial performance
Consumers	To meet needs of green consumer

Figure 2.3: Users and functions of environmental indicators, (Olsthoorn, et al., 2001)

Table 2.4 by Feng and Joung (2009) provides the sustainability indicator sets, which guides to select and adapt indicators according to the needs of the organization.

Table 2.4: List of Indicator sets (Feng & Joung, 2009)

Indicator Set	Components	Reference
Global Report Initiative (GRI)	70 indicators	http://www.globalreporting.org/ReportingFramework/ReportingFrameworkDownloads/
Dow Jones Sustainability Index (DJSI)	12 criteria based single indicator	http://www.sustainability-index.com/07_htmle/publications/

		guidebooks.html/
2005 Environmental Sustainability Indicators	76 building blocks	http://www.yale.edu/esi/ESI2005.pdf
2006 Environment Performance Indicators	19 Indicators	http://sedac.ciesin.columbia.edu/es/epi/downloads/2006EPI_Report_Full.pdf
United Nations Committee on Sustainable Development Indicators	50 indicators	http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf
OECD Core indicators	46 indicators	http://www.oecdbookshop.org/oecd/display.asp?sf1=identifiers&st1=972000111E1
Indicator database	409 indicators	http://www.Sustainablemeasures.com
Ford Product Sustainability Index	8 indicators	http://www.ford.com/doc/sr07-ford-psi.pdf
GM Metrics for Sustainable Manufacturing	46 Metrics	http://actionlearning.mit.edu/s-lab/files/slab_files/Projects/2009/GM,%20report.pdf
ISO 14031 environmental performance evaluation	155 example indicators	http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_ics_browse.htm?ICS1=13&ICS2=20&ICS3=10
Wal-mart Sustainability Product Index	15 questions	http://walmartstores.com/download/3863.pdf
Environmental Indicators for European Union	60 indicators	http://biogov.cpdr.ucl.ac.be/communication/papers/tepi99rp_EN105.pdf
Eco-Indicators 1999	3 main factors based single indicator	http://www.pre.nl/eco-indicator99/ei99-reports.htm

Moss and Grunkemeyer (2007) present the criteria of an indicator which is adapted from earlier research about sustainable measures (Sustainable Measures, 2009) and are listed below:

1. Measurable
2. Relevant
3. Understandable
4. Reliable/Usable
5. Data accessible
6. Timely manner
7. Long term oriented

Arenaa, et al. (2009) proposed an example of conceptual steps for the application of indicator framework which is presented in Figure 2.4.

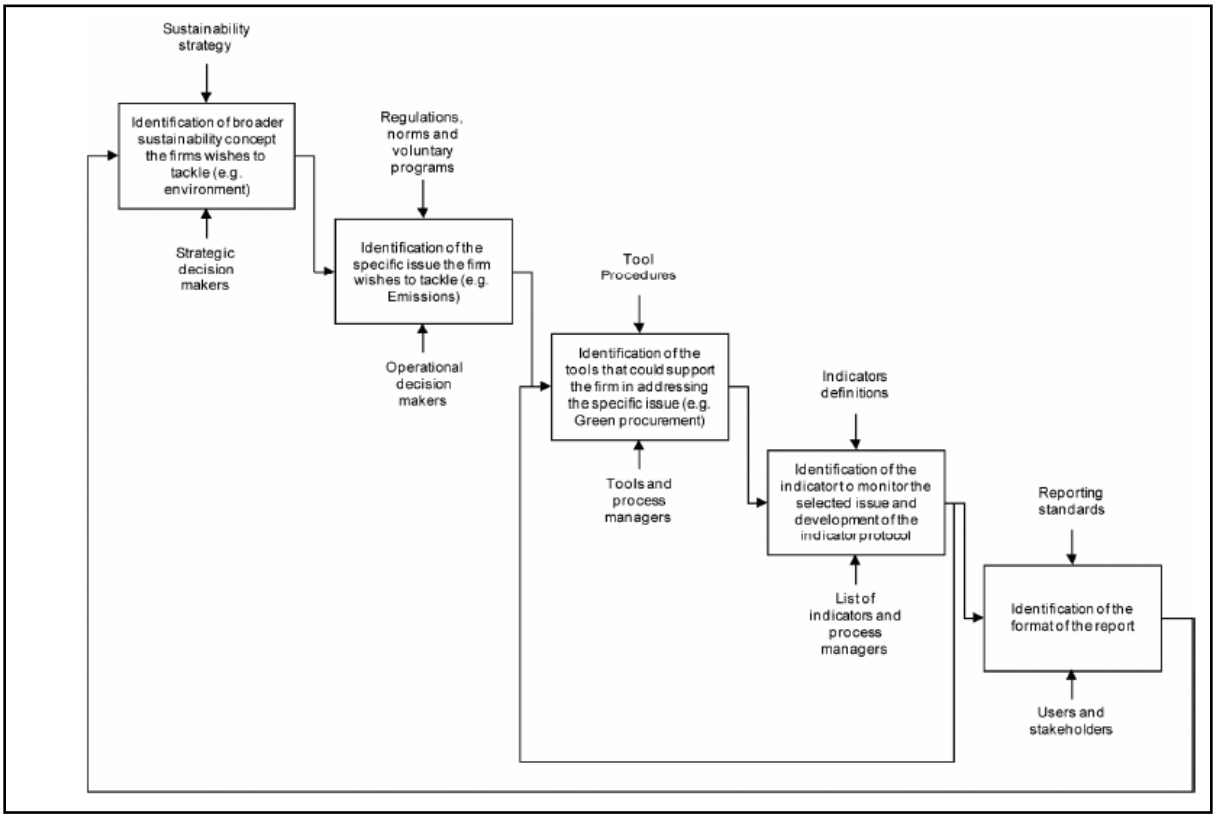

Figure 2.4: Conceptual steps for application of Indicator framework, (Arenaa, et al., 2009)

In general, indicators are categorized into different aspects based on the three dimensions of sustainability aiming to cover all aspects of sustainability in a clear and structured way. Among array of articles collected, Joung, et al. (2012) present NIST's indicator categorization concerning five dimensions namely *environmental stewardship*, *economic growth*, *social well-being*, *technological advancement*, and *performance management* and list first level sub categorization as in Figure 2.5 below.

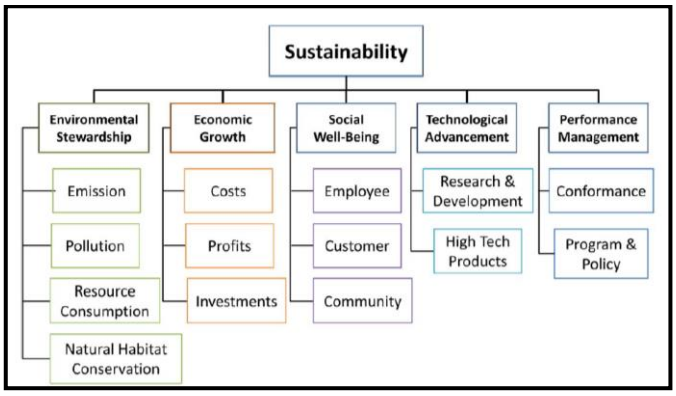

Figure 2.5: First level sub categorization, (Joung, et al., 2012)

There are other ways of classifying dimensions and aspects, for example, Winroth, et al. (2012) classify the hierarchy of sustainability indicators in an organisation as dimension, aspect and indicators as in Figure 2.6.

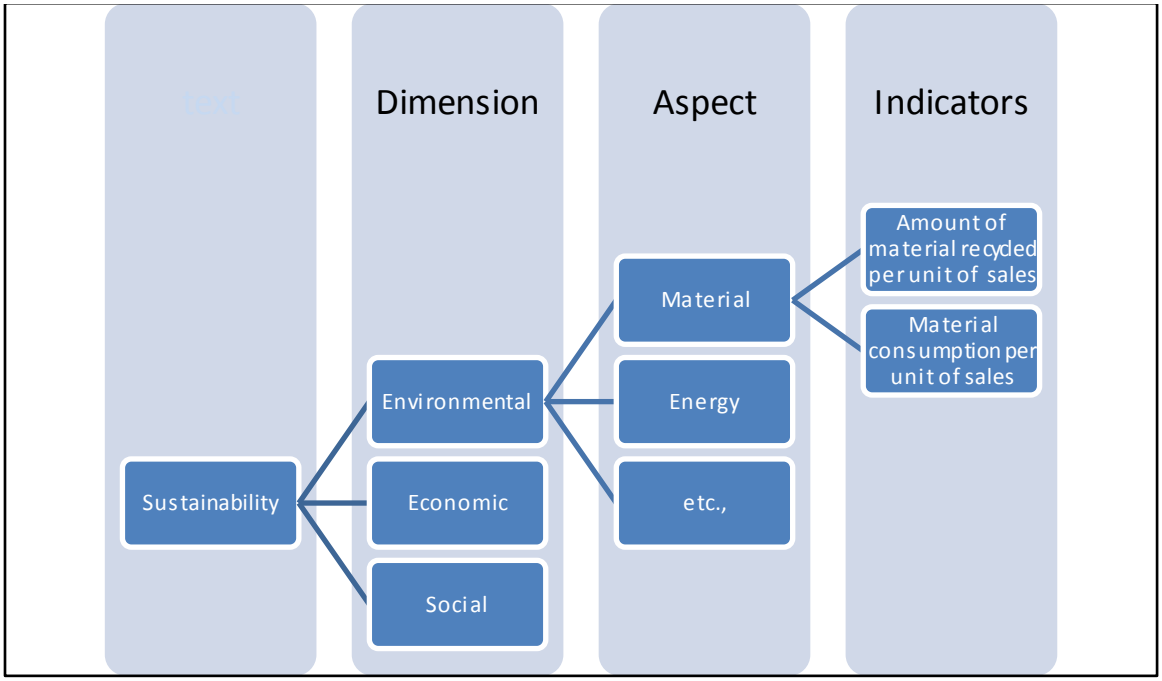

Figure 2.6: Categorization of sustainability dimensions, aspects and indicators, (Winroth, et al., 2012)

Further categorization on the first level could be made to identify the category and related indicators. For instance, resource consumption category in Figure 2.5 could be divided into various aspects as land use, material use, energy use and water use and also obtained from (Winroth, et al., 2012). An example about overall indicators for resource consumption is in Table 2.5 below. Some of the indicators developed were also used by one of the thesis authors in Chalmers Project course (Jansson, et al., 2014).

Table 2.5: Aspects and indicators for resource consumption category

Aspect	Indicators	Unit
Land use	Total land use	m^2
Material Use	Total Material usage	Tonnes per unit of sales
	Scrap rate	% of total material usage
	Total chemical usage	Tonnes per unit of sales
	Amount of material recycled	Tonnes per unit of sales
	Amount of recycled materials used	Tonnes per unit of sales
Energy Use	Use of renewable energy	% of total energy resources
	Energy use	kWh per unit of sales
	Energy efficiency	%
Water Use	Total water consumption	m3
	Recycled water	% of total water consumption

Factory/operational level indicators:

While the industry is facing challenges in sustainable development there is a need to understand sustainable operations. Key performance indicators are the most important performance information that enables organizations or their stakeholders to understand whether the organization is on the track or not (Gómez, 2013). To support goals on an organization level and link to production on operative level the wide concept of sustainability needs to be clarified and broken down to a more concrete level. Winroth, et al. (2012) present key performance indicators on factory level or operational level and the following requirement are presented for performance measures:

1) Derived from strategy
2) Clearly defined with an explicit purpose
3) Relevant and easy to maintain Simple to understand and use
4) Provide fast and accurate feedback
5) Link operations to strategic goals
6) Stimulate continuous improvement

2.10 Sustainability Reporting

Until now, many companies have been using only standard financial indicators to track their business effectiveness. Nowadays, due to demands from various parties (such as customers, suppliers, employees, national regulators, banks, insurance companies, shareholders, trade associations, local community), sustainability reports are emerging as a new trend in corporate reporting, integrating into one report the elements of financial, environmental, and social facets of the company (Krajnc & Glavic, 2005). Many organizations, especially manufacturing companies use sustainability reporting as an advertisement strategy by communicating their transparency in reporting their sustainability practices, economic investments, product development programs etc.,.

3 Methodology

This chapter explains the methods and tools used to study sustainability potential of GKN. Important steps were identified at the beginning of the thesis work and later it led to improvements and modifications according to ongoing results of thesis work. A schematic picture of the methodology is described below in Figure 3.1. The methodology is divided into two parallel topics of study, namely; study about sustainability in GKN and analysis of LPT case. The literature studies along with studied data were related and analysed to develop a sustainability indicators framework and suggest the guidelines for GKN.

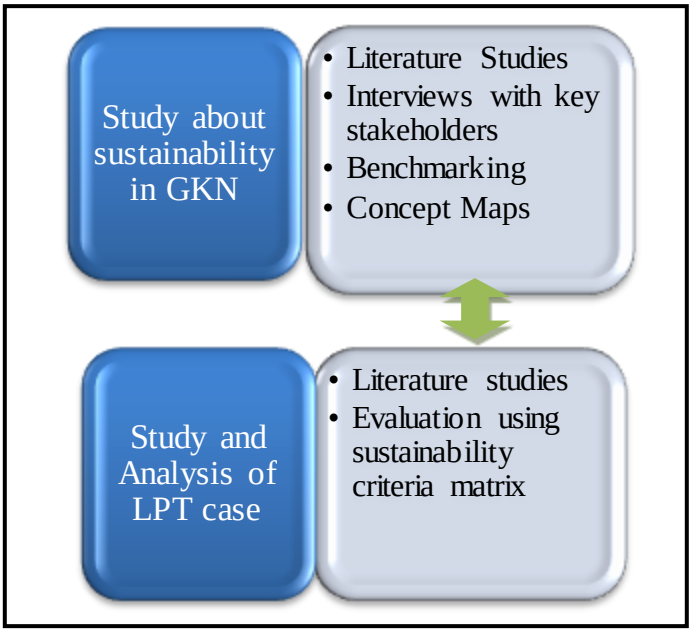

Figure 3.1: Methodology to study Sustainability Potential of GKN

The steps in methodology are explained in presented below and the results of using these tools in GKN are presented in chapter 4.

3.1 Literature Studies

As mentioned by Boote and Beile (2005), a literature review is to establish a theoretical framework for the topic and define key terms, definitions and terminology, identify studies, models, case studies etc., to support the topic and also to define and establish the area of study. In the same way, the studies performed helped in understanding the importance of sustainability in today's world, barriers in implementing sustainability concepts in a manufacturing industry and various sustainability approaches. Potential literature was obtained through Chalmers library search, science databases like Science direct and Springer link and also through Google scholar.

Literature studies were performed at every stage of thesis work to relate and analyse the results obtained. Literature studies at the initial stage were conducted to understand the concepts in sustainable manufacturing and to gather knowledge about current trends in sustainable development which provided guidance in identifying requirements to initiate with the thesis work, for e.g., interviews. Further, extensive literature studies support the development of indicators and deriving guidelines for GKN.

3.2 Study about sustainability in GKN

Understanding GKN and their sustainability level is essential to appreciate the sustainability efforts and to identify the gaps in the process of sustainable development. Understanding sustainability level means to understand the efforts taken, strategies and knowledge about sustainability values. Interviews with key stakeholders were aimed to study about goals, special initiatives, responsibility and challenges for sustainable development at department level. Concept map tool helped in understanding the awareness level among the GKN employees about sustainability concepts and its interrelation. Benchmarking with other companies aided to view and study about degree of sustainability focus and communication in GKN.

3.2.1 Interviews

Initially, meetings were held with key stakeholders at GKN to define the scope of the problem and to get an idea of the deliverables and expected results from this study. The stakeholders from the research department and management were involved in discussions about how this work could serve as a support to current research projects.

Interviews were held with key stakeholders during initial stage to describe the thesis and to establish valuable contacts as well for the thesis authors' understanding about the company, products and processes. Motive of interviews was also aided in understand sustainability related work and perception about sustainability in various departments in GKN. Key stakeholders chosen for interviews covered entire value chain from procurement till marketing and communications department in GKN, Trollhättan. The interviews were conducted in a semi- structured form and the main objectives were:

1) To understand the level of sustainability knowledge and new initiatives within the different functions of the company
2) Challenges related to sustainability

Functional departments related to LPT case value chain were chosen for interviews. Departments covered for interviews are as follows,

1. Environmental Engineer
2. Purchasing and supplier requirements
3. Material Control and procurement
4. Forging Process Engineering
5. Product development
6. LPT Production support functions
7. LPT component leader
8. Operation CNC control and tooling
9. Machining methods specialist
10. Maintenance & Support
11. Facilities & Environment
12. Marketing department for customer relations
13. Business Manager
14. Communications

Interview Questions:

The interviews were semi-structured and the questions were framed to understand the initiatives, goals, KPIs, challenges and strategy related to sustainability in respective departments. Further discussions led to understanding issues in LPT case and improvement suggestions. The common topics and questions discussed with all managers are as follows:

1) **Knowledge about sustainability**
   a) Are you aware of sustainability importance and how it could affect our future?
   b) How many times have you heard about sustainability initiatives?
   c) Have you identified any goals related to sustainability?
   d) If yes, what are the initiatives to align to those goals?
   e) What are the KPIs for departments?
   f) Are the KPI's aligned towards sustainability goals?
   g) Does the department have any strategy towards sustainability?
   h) Any analysis done till now to reduce economic waste?
   i) Any focus groups on sustainability in your department?

2) **Have steps taken towards**,
   a) Implementing lean
   b) Reducing lead time
   c) Changing production methods
   d) Reducing material input
   e) Reduce scrap
   f) Reducing energy consumption
   g) Reducing product cost
   h) Reducing work load
   i) Improving skills of workers

3) **Personal Opinions:**
   a) Sustainability issues
   b) New production technology
   c) Forging methods
   d) Reducing wastes

These questions were adapted to department functions and based on responses, discussions were proceeded to fulfil the objective of interviews.

3.2.2 Benchmarking

It is important to understand the sustainability practices followed in other companies to learn the position of GKN and their efforts towards sustainability. Further, sustainability has become a trend where companies use their sustainability practices as a marketing strategy to support the company in terms of sustainable technology development. Increasing volume of air traffic and similar issues are placing greater ecological demands on the aviation industry. The European aviation industry and research community have already pledged to make air traffic more environmentally friendly by committing to a strategic roadmap that sets out targets from now until the year 2050. In a similar manner, Wong, et al. (2013) claim that environmental reputation as an important organizational objective for manufacturers is a valuable intangible asset to sustain a company´s growth.

Limited level of benchmarking was performed to study how other companies are working towards sustainability and how do they promote themselves concerning sustainability programs and initiatives. By "limited level of benchmarking" the thesis authors mean that the comparison between these companies was made based only on their annual reports obtained from their respective web pages. Hence, annual reports of four companies were studied. This work will be useful to compare with the sustainability practices in GKN Aerospace and to identify initiatives and potential methods that GKN could implement to improve its place in sustainability performance, as well as understand their potential to highlight current work related to sustainability to strength their sustainability image. The companies were analysed on the following topics as these are key highlights of an industry working towards sustainability:

- Sustainability strategy
- Sustainability practices
- Sustainability indicators
- Future goals and Commitments
- Association with External institution programs and Recognitions
- Focus group on sustainability

Concerning the three dimensions of sustainability the environmental and social aspects have been the most central factors in this comparison. However, economic indicators that are related to specific environmental practices will be presented. The aim of this benchmarking is not to present all common indicators used, but to identify special efforts and initiatives in terms of the three dimensions of sustainability. Following three companies were studied along with GKN,

- SKF
- GE
- MTU

Company SKF was selected based on Stakeholder interest and GE is the customer and MTU is the competitor and customer to GKN. It is interesting to study the sustainability practices in customer and competitors as it will be helpful to GKN to inspire and adapt the successful practices followed in other companies for their progress.

3.2.3 Concept map

Concept map is an assessment tool to study awareness level among individuals and to study the cognitive domain (Segalàs, et al., 2010). Concept map tool was used to study the level of employee´s awareness of sustainability values and interlinking related concepts. A concept map is used to show relations between concepts which are represented by boxes. These workshops were conducted by gathering small groups and the participants were asked to draw a concept map. It is important that the concept maps are analysed consistently in a standardized way to increase the efficiency of the result and to make the result comparable with other companies.

Employees included management groups, R&D team and LPT case production group who could be responsible for sustainable development. They were provided with an A3 poster with the question *"What is sustainability for you?"* and based on that question, they wrote topics related to sustainability concepts and interrelating the same. Sustainability is a large topic and the meaning of the concept is spread and wide, where as it is often described as three dimensions namely social,

environmental and economic. Prime requirement was to understand if the GKN employees were able to relate and appreciate all three pillars of sustainability with their work and experience in GKN. As a result, the concepts can be calculated, e.g. the percentage among the employees that have assigned environment, social and economic related topics can be calculated. This could be useful to motivate the degree of sustainability efforts in the company towards the path of sustainable development.

This method could be used to analyse the current state of awareness and to see in what way the knowledge among the employees is lacking taking the three dimensions of sustainability into account. The result of the current state will serve as a comparison for a future state later when the conceptual maps are performed and changes in awareness level can be measured among the employees.

According to Segalàs, et al. (2010), conceptual maps only evaluate the cognitive domain, meaning how the employees understand the notion of sustainability. Further, the author presents different indexes to evaluate the result of the concept maps. First, there is a category relevance index (CR), measured as percentage of concepts devoted to a certain category. Second, there is complexity index which measures how well the concepts are interrelated.

Once all the concepts maps were done, calculations were made according to the formulas presented below.

Categorization of concepts and categories

Segalàs, et al. (2010) categorize various concepts under four categories as presented in Table 3.1. This was used as base to understand and define the presented concepts under each category.

Table 3.1: Categorization of concepts presented by Segalàs, et al. (2010).

Categories -4	Sub Categories - 10	Concepts and aspects considered
1. Environment	1. Environment	Pollution, degradation, conservation, biodiversity, ecological footprint, emissions, …
	2. Resource scarcity	Non- renewable resources, depletion of materials, …
2. Social	3. Social impact	Quality of life, Health, Risk management, …
	4. Values	Ethics, Respect for traditions and culture, …
	5. Future (temporal)	Future generations, scenario analysis, forecasting, back- casting, …
	6. Unbalances	The equity dimension. North- South cooperation, fair distribution of goods, fair use of resources
3. Economic	7. Technology	Best Available Technologies, industry, efficiency, clean technologies, energy, impact of technology,
	8. Economy	Role of economy, fair trade, consumption patterns, …
4. Institutional	9. Education	Role of education, rise of awareness, education institutions, media's role in education or disinformation, …
	10. Actors and stakeholders	Role of governments, rules, laws, international agreements, individuals and societal stakeholders, …

Presentation of formulas

Once the concepts under various categories were identified, below formulas were used for calculating concept distribution and category relevance index presented by Segalàs, et al. (2010).

Concept distribution (CD) among categories

This evaluates the distribution of concepts among categories, measured as percentages of concepts devoted to a certain category:

$$CD_i = \frac{NC_i}{\sum_{i=1}^{i=N_{Ca}} NC_i}$$

NC_i: The number of concepts per employee per category

N_{Ca}: The number of categories

SC_i: The percentages of employees who assign concepts to a certain category:

$$SC_i = \frac{NE_i}{NE}$$

NE: Sample number of employees who participate in the observation

NE_i: Number of employees that assign categories to a specific category

CR_i: The Category relevance is calculated by multiplying CD_i and SC_i:

$$CR_i = \frac{CD_i \times SC_i}{\sum_{i=1}^{i=N_{Ca}} CD_i \times SC_i}$$

Complexity index (CO)

This evaluates how far employees develop and inter-relate the different concepts and categories.

$$CO = \mathrm{NC} \times L_{Ca}$$

NC: Average number of concepts per employee

L_{Ca}: Relative measure of the connections between concepts that belong to different categories:

$$L_{Ca} = \frac{\sum_{j=1}^{j=NE} NL_j}{N_{Ca} \times NE}$$

NL: the number of inter- category links between concepts that belong to different categories

NE: Sample number of employees who participate in the observation

N_{Ca}: The number of categories

These two indexes will be calculated to rate the understanding level and inter relating the concepts among different categories.

3.3 Study and Evaluation of LPT case using Criteria Matrix

To get a closer view, the product LPT case was studied for identifying the issues related to sustainability values and to identify the sustainability potential. In this part of the work, the Sustainability Criteria matrix (Hallstedt, 2014) developed at GKN was helpful to evaluate and study the gaps regarding sustainability of LPT case. For evaluating using criteria matrix, sustainability indicators were developed. A better understanding about the benefits of these criteria aims to close the gap between the research department and operational decisions in the company.

GKN's researcher and product design department together developed a sustainability criteria matrix which consists of criteria for each life cycle phase. The criteria matrix is based on four principles of sustainability which covers the ecological and social dimensions. The thesis work included study about criteria matrix to evaluate the LPT case.

Four Principles of Sustainability

The four principles of the sustainability matrix criteria are defined and the objectives of respective principal are presented below as mentioned in Robert, et al. (2002).

1) Nature is not subject to systematically increasing concentrations of substances from the Earth´s crust.

   Objective:
   Eliminate our contribution to systematic increases in concentrations of substances from the Earth's crust. This means substituting certain minerals that are scarce in nature with others that are more abundant, using all mined materials efficiently, and systematically reducing dependence on fossil fuels.

2) Nature is not subject to systematically increasing concentrations of substances produced by society.
   Objective:
   Eliminate our contribution to systematic increases in concentrations of substances produced by society. This means systematically substituting certain persistent and unnatural compounds with ones that are normally abundant or break down more easily in nature, and using all substances produced by society efficiently.

3) Nature is not subject to systematically increasing degradations by physical means

Objective:

Eliminate our contribution to the systematic physical degradation of nature through over-harvesting, introductions and other forms of modification. This means drawing resources only from well-managed eco-systems, systematically pursuing the most productive and efficient use both of those resources and land, and exercising caution in all kinds of modification of nature.

4) In the sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.

Objective:

Contribute as much as we can to the meeting of human needs in our society and worldwide, over and above all the substitution and dematerialization measures taken in meeting the first three objectives. This means using all of our resources efficiently, fairly and responsibly so that the needs of all people on whom we have an impact, and the future needs of people who are not yet born, stand the best chance of being met.

These four principles were aligned to the impacts of five life cycle phases of product namely,

1. Material source
2. Production
3. Distribution
4. Use and Maintenance
5. End-of Life

Each life cycle phase implies the following:

1) Material Source: Materials and chemicals that are used for the product components and/or its production.
2) Production: Production by suppliers of sub-components & materials, as well as production of products at the own company.
3) Distribution: Transportation of materials, substances and products connected to the company products and its production.
4) Use and Maintenance: Activities and design decisions that affect the sustainability impact during the usage phase.
5) End of Life: Activities and design decisions that affect the sustainability impact during the end of life phase.

Hallstedt (2014) presents different categories for criteria below that are included in the criteria matrix:

1) Strategic sustainability criterion: is the ideal long-term sustainability target and something to strive for.
2) Tactical sustainability design guideline: define the prioritized sustainability aspect that supports a development towards the related long-term strategic sustainability criterion.
3) Absolute sustainability requirement criterion: is a short-term sustainability target that is required for design solutions of today.

3.3.1 Evaluation using criteria matrix:

For LPT case, two life cycle phases' namely Material source and Production was selected for evaluation. In order to evaluate these criteria, indicators were required to quantify the results of

evaluation. Hence, through literature studies, indicators were developed for each criterion. Since the matrix had ecological and social criteria, related indicators were used for evaluation. Sustainability is based on long term decisions and actions, but to support these decisions in the short term and to get acceptance from management, economic values are of high importance. Therefore, a complementation with economic criteria is required in order to concretize the benefits of introducing these criteria matrix into practice. But economic indicators were not used because it required extensive work and time and so it was indicated to GKN for further research.

3.3.2 The sustainability compliance index matrix

The sustainability compliance index matrix explains the different levels of compliance with respect to each criterion. This defines the five levels of compliance for criteria namely 0, 1, 3, 6 and 9, where 0 and 9 represents the worse and best condition of sustainability compliance respectively. This is easy to use and understand. It can be used to evaluate and follow a development of a concept and visualize the progress towards a more sustainable solution (Hallstedt, 2014). This serves as a good guide to find the issues present in a product or concept or process and to define improvements aligning to sustainability. This compliance index model aims to assess the current level of compliance to sustainability and hence by identifying the issues and opportunities to the next sustainability level for LPT case. This was analysed and assessed with the help of responsible persons from Material development, Environmental Engineer, Production of LPT case, Procurement and Health and Safety departments.

3.3.3 Data Collection for Evaluation of LPT case

Data collection was performed through consultations and dialogues with responsible persons from environmental, facility, health and safety and LPT case production department of GKN and also referring the concerned reports and documents of GKN. Firstly, value and relevance of criteria matrix was explained and data was collected through complete understanding between thesis authors and responsible persons of GKN.

4 Results

This chapter explains the results obtained from performing Interviews, Concept Maps, Benchmarking and Evaluation of LPT case using Criteria matrix.

4.1 Interviews

Feedback from stakeholders regarding sustainability was similar in most of the topics discussed. It was a common expression from all stakeholders that sustainability word is very rarely used in the organization and interest from higher management. Findings from the interviews were that there was no awareness or internal communication about GKN PLC's core values, which included all principles about three dimensions of sustainability. Possibly, in the company there is little knowledge that "Sustainability" is integrated in several other terms internally, e.g. *ThinkSAFE* which is a social responsibility initiative towards a safer working environment. Other findings were that there is no strategy or goals related to sustainability, but still some departments understand and use their KPI's as connected to sustainability. It was important to study the environmental department work and their established goals for 2014 related to waste handling and reduction (hazardous and non-hazardous), energy consumptions, reducing silver in surface treatment process, discharge of VOC and reduction of fuel consumption for engine testing.

4.1.1 Sustainability initiatives

The sustainability initiatives are as follows:

1) Lean steering committee in production of LPT case
2) Continuous energy reduction effort from Facility department
3) Working on Imparting sustainability aspects in conceptual stage of PDP
4) Criteria and supporting tools with support from BTH
5) Environmental impact assessment (EIA) was conducted for few products and improvements
6) GRANTA database to be implemented
7) Identifying suppliers for reduced Tool cost
8) Improved cleaning methods to ensure good quality
9) Extended value stream mapping
10) Efficient packaging in containers
11) Recycling of all production wastes and using recycled materials in forging
12) All chemical wastes are cleaned before releasing to environment
13) Almost 90% recycled water for production

4.1.2 Challenges related to sustainability

General and specific department potential for sustainability were discussed with stakeholders and they are listed below:

General

1. To implement the research areas to practice
2. To change people view and support to sustainability
3. Using sustainability concepts

4. To improve responsive rate and pro- activeness
5. To increase sustainability awareness
6. Create supporting tools, define goals, strategy, set criteria and indicators related to design and production

Material

1. Forging design for low material input
2. Increase material Efficiency
3. Reduce forging cost and material cost to shift more value to the production and machining cost

Design

1. Contract issues: GKN does not lead development of LPT, It is challenging for GKN to get higher influence on e.g. Product Design
2.

Process

1. Increasing tool life
2. Achieve higher cutting speed

Production

1. Time required for implementing fully operated lean
2. To improve Production flow
3. Reduce set up time
4. Reduce production lead time
5. Reducing Lead time
6. Improving Lean methods
7. Supplier controlled by customers
8. Communication with production is crucial to support just in time as well as keeping inventory low.
9. Reduce production cost
10. Making more efficient Production Methods

Maintenance

1. Reduce Machine breakdowns
2. Low reliability on machines
3. To improve cooperation between production and maintenance
4. To implement preventive maintenance system

Facility

1. To reduce the energy consumption
2. Separate control and monitoring for each shop
3. Improving Heating Methods by heat recovery
4. Get employees to turn off electrical equipment when not in use

4.2 Benchmarking

GKN aerospace and three companies "Svenskakullagerfabriken" (SKF) General Electric Aircraft Engines (GEAE) and MTU Aero engines were compared and the assessed on the same reference base, in the sense that annual reports were studied extensively based on the topics mentioned in :

A short description of results is explained below. Results of the different topics of study among these companies are presented in appendix A.

4.2.1 SKF

SKF has a strong history of work towards sustainability since they started reporting its environmental performance since 1989. Company started fully integrated reporting since 2011 and it includes financial, social and environmental aspects. SKF has special report on SKF's policies and practices for sustainability which was a clear evidence to understand their work explicitly. The company has a *Beyond Zero* strategy which strives to reduce the environmental impact from SKF operations and Products and therefore enhancing the ability for the business to do more with less and thereby creates sustained competitive advantage (SKF, 2013).

4.2.2 GE

GE has an exclusive document on sustainability reporting covering all three aspects people, planet and economy. By people GE mean their employees, communities, customers and shareholders, planet includes environment and resource management, products and services and economy covers aspects of public policy governance and sustainable systems. They have a GE citizenship advisory panel supporting company's approach to sustainability. GE has a special focus program for sustainability namely *Ecomagination* which is GE's commitment to build innovative solutions for today's environmental challenges while driving economic growth. They also perform a materiality analysis which is the intersection of issues that are important to stakeholders and issues that are the most relevant and significant to the success of GE's business.

Message of GE's CEO is *"Both Ecomagination and Healthymagination tie the sustainability message to the company's portfolio, highlighting the fact that GE is both a responsible organization in its own right and that it also helps customers around the world become sustainable"* (GE, 2013).

4.2.3 MTU

MTU has similar production as GKN and is thereby one of GKN´s competitor and customers (having Pratt and Whitney and General Electric as customers) in the market of low pressure turbine cases and other components within the aviation industry.

The MTU principles are based on six pillars:

- Technology and Growth
- Cooperation and Conduct
- Staff and Management
- Partners, Customers and Shareholders
- Environment and Society
- Materiality matrix: identifying important sustainability topics

At MTU, sustainability is one the main principles and MTU is working with sustainable product development as a part of their long-term Clean Air Engine Technology program which aims to develop more eco-efficient engine products. One of their innovation products is the Geared Turbofan which is a result of years of research and preliminary studies by MTU engineers, and considerable financial investment on the part of the company. MTU is already looking ahead to products and new technologies that go beyond current developments. This Clean Air Program helps them maintain focus on development of new technology and engineering groups are established and focused on sustainability work (MTU Aero Engines, 2013).

4.2.4 GKN

GKN aerospace strategy includes sustainability saying "*Our goal is to have a positive impact on the environment and communities in which we operate. We aim to operate in a sustainable, ethical, efficient and safe manner".* As a matter of fact, this means that GKN aerospace is thinking about sustainability aspects and implementing processes for the same.

Respective improvements include the following (GKN PLC, 2013):

- Creating Operational Excellence through Lean manufacturing and innovative engineering
- Creating a long term sustainable value through 12 Promises
- Development of light weight, Fuel efficient products reducing carbon emissions
- Development of alternative materials
- ISO140001
- Safety programs and reduced accidents

At the same time, it is hard to see any future goals or commitments relating sustainability. Unlike other companies, there is no sustainability programs/focus groups established until now. Also, it was seen that, safety issues were taken into high consideration and improvement are continuously recorded through safety training and programs. Below

Table 4.1 provides the comparison of GKN with other three companies on different topics. These topics were identified as common between three companies and their levels were decided from studying the reports as mentioned above.

Table 4.1: Comparison of GKN with three companies on topics of study

Company	Sustainability indicators for reporting	Clear Strategy including sustainability	Clearly communicated future Goals and system for tracking sustainability issues	Committed sustainability focus groups	External Institution support	Awards and recognitions
GKN	✓✓✓	✓	✓	×	×	×
GE	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
SKF	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
MTU	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓

Table 4.2: Legends of symbols used in Table 4.1

✓✓✓	All three dimensions of Sustainability are well understood and explained
✓✓	Sustainability concepts are understood and efforts are explained to an extent
✓	Sustainability is only mentioned and initiatives or steps are not explained
×	No information related to Sustainability

4.3 Concept Map

On compiling the results from concept maps, the category relevance index was calculated for different concepts which are presented in the bar chart in Figure 4.1 and Figure 4.2.

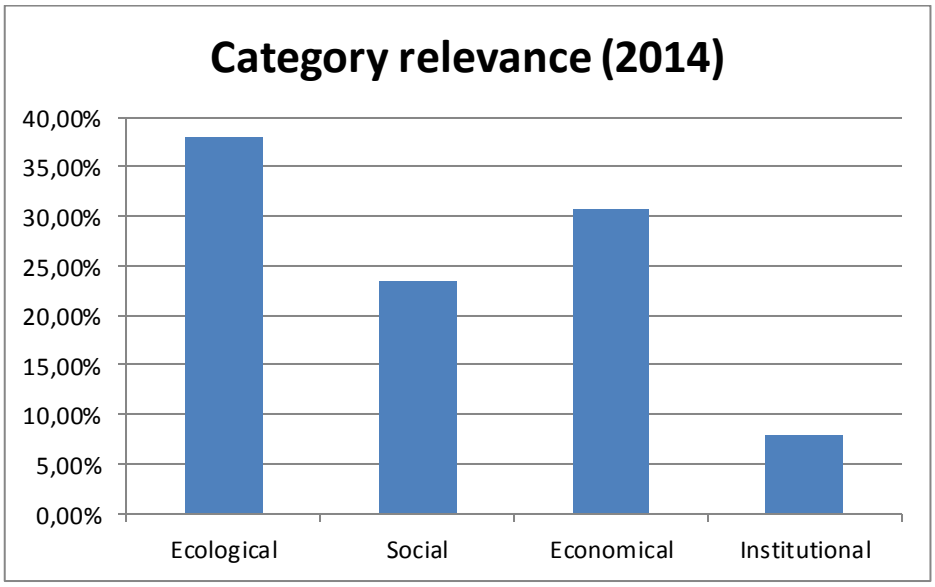

Figure 4.1: Spread of knowledge concerning four dimensions of sustainability

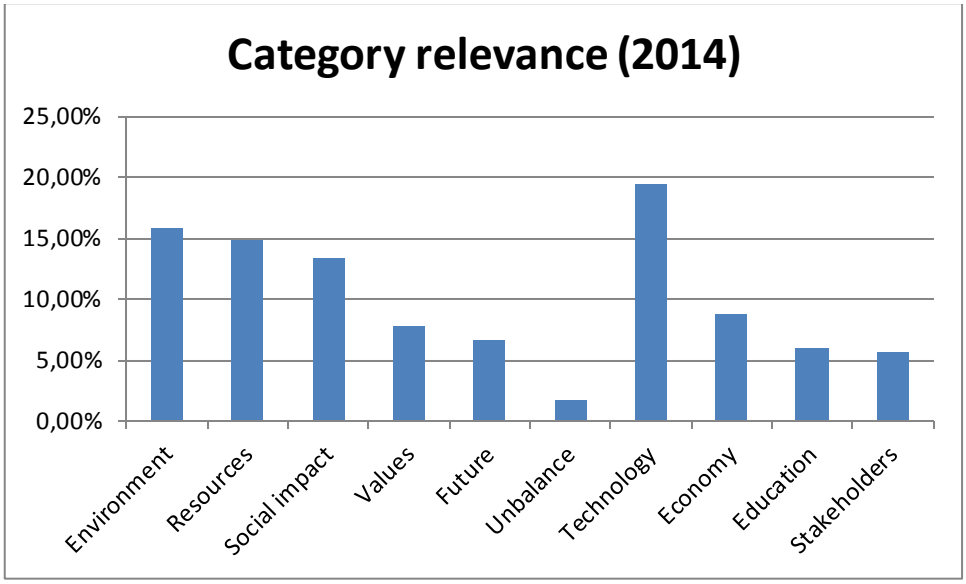

Figure 4.2: Spread of knowledge for sub categories

A category relevance index (CR) provides information about what employees at GKN think sustainability is most closely related to.

The employees´ knowledge was analysed concerning the triple bottom line in order to see if employees at GKN relate sustainability to environmental, social and economic concepts. Figure 4.2 represents the category relevance index for the triple bottom line and for institutional related concepts. From interviews it was concluded that environment is most what employees at GKN relate sustainability to. Further, GKN has developed *ThinkSafe* program which is an initiative focusing on health and safety at the company (GKN, 2014). Accordingly, employees relate to social aspects but not to the same extent as for environmental and economic aspects. It was seen that employees at GKN relate less institutional aspects to sustainability. Furthermore, when these four concepts were broken down into a total of 10 concepts it was seen that employees at GKN relate mostly technology concepts to sustainability, as shown in figure 4.2.

Secondly, the complexity index was 3.87. The purpose of calculating the complexity index was to analyse the complexity in knowledge among 30 employees at GKN from different functions within the company. In more detail, it revealed if employees at GKN interlink concepts from different categories. This index can be compared in future with a new number, if concepts maps are performed later on, for instance in six months, to see how the employees develop understanding about the sustainability concepts.

4.4 Evaluation of LPT case using Criteria Matrix:

The results obtained for two lifecycle phases corresponding to four principles are provided below. It is important to note that the measurements and studies were restricted to one of the variants of LPT case which is mentioned as *abc* in this thesis report.

4.4.1 Life Cycle Phase: Material source

Evaluation results of the material source life cycle phase under each principle is explained in the following sections; The indicators and measurements corresponding to material life cycle phase is presented in Table 4.3 and the current level of compliance in Figure 4.3.

First Principle:

Indicator and measurements:

The material is considered to be low risk if they have secured future availability. Moreover, following factors need to be considered, i) natural availability; ii) commercial availability; iii) competition of this material; iv) number of potential supplier; v) maturity of materials and processes, vi) conflict material/metal.

The relevant indicators are "% of risk materials per unit of product" and "% of conflict materials per unit of product". The material composition for LPT case was obtained to study the risk materials in product. It was required to get lot of details and perform research which was time consuming to analyse the above mentioned factors. Also, the conflict materials were not been in focus till now in GKN and so measuring the % of risk materials and conflict materials were not possible by thesis authors.

Current level of Compliance:

For first principle, the compliance level is zero. It was observed that GKN has not focused on risk materials or conflict materials and they don't have a system of following the same. But currently research is going on implement GRANTA database, which is developed by The Material Data Management Consortium (MDMC), Granta Design (GRANTADesign, 2014).

Second Principle:

Indicator and measurements:

SIN-list (SIN, 2013) and REACH candidate list (European chemical agency, 2013) are restricted materials list which are not allowed to be used in the organisation. As per this guideline, the design should not be approved if the chemicals or materials are in REACH candidate list. And the usage of SIN-list chemicals should be reduced over a period of time.

Out of 26 chemicals used for production of LPT case:

- Number of materials in REACH candidate list per unit of product -1/26
- Number of materials in SIN list per unit of product - 4/26

Current level of Compliance:

For second principle, the compliance level is one. GKN has a database that lists the chemicals used in GKN which includes in REACH and SIN list and also other restricted lists. This means GKN keeps a track of restricted lists. Currently, substitution processes of these chemicals are going on and the alternative of above mentioned chemical in REACH list have been identified and it is in approval stage at present.

Third Principle:

Indicator and measurements:

The relevant indicator is "Amount of materials that are restricted to use (causing physical degradation of nature) per product". Since there is no restriction lists pertaining to this specific criteria in GKN, it was not possible to identify the number of materials under this category for LPT case.

Current level of Compliance:

For third principle, the compliance level is zero. GKN do not know if the materials that are used are extracted using physical degradation of natural resources. In short, GKN does not have such regulations with their suppliers. This is new to GKN to study about Material suppliers manufacturing sites and related physical degradation due to processes etc.

Fourth Principle:

Indicator and measurements:

This criterion by itself explains the requirement and hence the indicator could be Yes/No which says "Have a certificate (yes/no) showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production?"

The answer is No as GKN does not have any regulation till now supporting the fourth principle.

Current level of Compliance:

For fourth principle, the compliance level is zero. This means GKN do not know if conflict materials are used for product components and/or its production. Also, they do not have a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production. These issues have not been in focus till now in the organisation.

4.4.2 Life Cycle Phase: Production

Evaluation results of the production life cycle phase under each principle is explained in the following sections. The indicators and measurements corresponding to production cycle phase is presented in Table 4.4 and the current level of compliance in Figure 4.4.

First Principle:

Indicator and measurements:

The indicators and measurements are as follows:

- % of renewable and non-renewable energy sources used for production of LPT case: This was not obtained in specific for LPT case but for the whole Trollhättan plant uses 66% renewable energy sources and remaining 34% of non-renewable energy sources.

- Efficiency of energy usage of production process: There is no provision in GKN to measure efficiency of production process.
- Global warming potential of energy consumption of production process: GWP could not be obtained specific to GKN's production process only.
- Amount of production wastes (solid and liquid) from production process before recycling (kg): 100 kg/per product for abc LPT case
- GWP (tons of CO2 equivalent) emissions from production wastes: Not available

Current level of Compliance:

The Current level of Compliance of compliance is six, which is a positive aspect of GKN. Almost 100% of the material wastes are recycled and 2/3 of energy resources are renewable. The recycling process is followed for all type of material wastes and they have standard regulations on separating the different materials before sending to the recycling centre due to which the revenue is increased. GKN in Trollhättan has 66% of renewable energy sources and remaining non-renewable. They have a continuous energy reduction plan and related future goals are also set for the plant.

Second Principle:

Indicator and measurements:

- Amount of material waste in production sites in Reach list – No details available
- Amount of material waste in production sites in SIN-list –No details available

Current level of Compliance:

For second principle, level of compliance is 1. GKN follows a clean waste treatment process and all chemical wastes are cleaned and decomposed to CO_2 and water before sending to the atmosphere, but the solid wastes are send to landfill following all regulations, but the composition of the wastes are not yet analysed to know if they are in REACH list and SIN-list. All the solid wastes are categorized according to hazardous level and extensive cleaning process is performed before sending to recycling centre.

Third Principle:

Indicator and measurements:

- % of recycled and fresh water used for production: For LPT case, 100% recycled water is used for production
- Amount of waste (solid and liquid) causing physical degradation of nature (kg): No details available

Current level of Compliance:

For third principle, current level of compliance is 6, which means there is a constant reduction of clean water usage and also reduction of waste and spill from production process. There is no spill in production of LPT case and material wastes are reduced over the past years. For LPT case abc, 66%

of input material is removed through machining which becomes an interesting factor for GKN to concentrate.

Fourth Principle:

Indicator and measurements

- Number of injuries
- Number of occupational diseases
- Number of lost days and absenteeism
- Total number of work related fatalities in the production

The details pertaining to these indicators were not obtained during the work. Since the annual report of GKN constitutes the details, the measurements should be available.

Current level of Compliance:

The current level of compliance is 6. Actions for safety are visualized in GKN through the safety plan and related communication. The sustainability report also contains the data about number of lost time accidents and number of days/shifts lost due to accidents and occupational ill health. GKN has a goal of zero preventable accidents and improvement of safety through *ThinkSAFE* program and safety audits. Safety audits and processes could be improvised according to feedback from employees and respect to technology changes.

Below Table 4.3 and Table 4.4 mentions the indicator and measurements made for Material source and production life cycle phase.

Table 4.3: Material source phase indicators and measurements

Life cycle phase	Principle	Developed indicator	Measurement
Material Source	1	1) % of risk materials per unit of product 2) % of conflict materials per unit of product	No details available
	2	Number of materials in REACH candidate list per unit of product	1/26
	2	Number of materials in SIN list per unit of product	4/26
	3	Have the raw materials extraction site (Supplier) is complying the local laws and does not cause physical destruction of nature? - YES or NO	No details available
		% of materials that is restricted to use(causing physical degradation of nature) per unit of product	No details available

	4	Have a certificate (yes/no) showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production?	No details available

Table 4.4: Production phase indicators and measurements

Life cycle phase	Principle	Developed indicator	Measurement
Production	1	% of renewable and non-renewable energy sources used for production of LPT case	For the whole Trollhättan plant 66% renewable energy sources and remaining 34% of non-renewable energy sources
		Efficiency of energy usage of production process	No details available
		GWP (tons of CO2 equivalent) of energy consumption of production process	No details available specific to LPT case
		Amount of production wastes (solid and liquid) from production process before recycling (kg)	100 kg/product for abc (66.66% of input material)
		GWP (tons of CO2 equivalent) emissions from production wastes	No details available
	2	Amount of material waste in production sites in Reach list	No details available
		Amount of material waste in production sites in SIN-list	No details available
	3	% of recycled and fresh water used for production	100% recycled water
		Amount of waste (solid and liquid) causing physical degradation of nature (kg)	No details available
	4	Number of injuries	Not obtained
		Number of occupational diseases	
		Number of lost days and absenteeism	
		Total number of work related fatalities in the production.	

Below Figure 4.3 and Figure 4.4 show the current level of compliance of LPT case in the sustainability compliance index matrix.

Life cycle phases		Sustainability Principle 1: Nature is not subject to systematically increasing concentrations of substances from the Earth´s crust.		Sustainability Principle 2: Nature is not subject to systematically increasing concentrations of substances produced by society.		Sustainability Principle 3: Nature is not subject to systematically increasing degradations by physical means.		Sustainability Principle 4: In the sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.
Material Source: *materials and chemicals that are used for the product components and/or its production.*	9	*No risk-materials used according to raw material lists .*	9	*No materials for products and/or production used that contain or result in emissions of substances included in the SIN-list.*	9	*No use of raw materials & chemicals and/or its manufacturing sites that cause physical degradation of Nature.*	9	*No materials and chemicals used that cause violation of human needs.*
	6	*Move towards risk-free material usage with high natural availability, high commercial availability, high maturity of materials and processes, materials with low competition of this material and good enough number of potential suppliers.*	6	*A phase out/substitution plan is followed for those chemicals/materials used that is included in the SIN-list.*	6	*Have completed more than 50% of the substitution plan for raw materials & chemicals and/or its manufacturing sites that cause physical damage to Nature.*	6	***i)** No usage of conflict materials for product components and/or its production is used. **ii)** Have a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production.*
	3	*No conflict materials/metals are used but other risk materials are used.*	3	*No usage of materials that contain or result in chemicals that are included in the REACH-candidate list, but chemicals/materials included in the SIN-list are used.*	3	*Have a substitution plan for raw materials & chemicals and/or its manufacturing sites that cause physical damage to Nature.*	3	***i)** No usage of conflict materials for product components and/or its production is used. **ii)** Do not know if there is a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production.*
	1	*Conflict materials and other risk materials used in the alloys today*	1	*Materials that contain or result in chemicals that are included in the REACH-candidate list are used.*	1	*All raw materials & chemicals and/or its manufacturing sites used, cause , physical degradation of Nature.*	1	***i)** Conflict materials for product components and/or its production is used. **ii)** Do not know if there is a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's*
	0	*Do not known if and what risk materials that are present in the alloys today*	0	*Do not known if materials or chemicals used is included in the REACH-candidate list .*	0	*Do not know if or which of the raw materials & chemicals and/or its manufacturing sites used, that cause physical degradation of Natur e.*	0	***i)** Do not know if conflict materials for product components and/or its production is used. **ii)** Do not know if there is a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production.*

Figure 4.3: Current Compliance level for Material source life cycle phase, based on SCI matrix developed by Hallstedt (2014).

		Sustainability Principle 1: Nature is not subject to systematically increasing concentrations of substances from the Earth´s crust.		Sustainability Principle 2: Nature is not subject to systematically increasing concentrations of substances produced by society.		Sustainability Principle 3 Nature is not subject to systematically increasing degradations by physical means.		Sustainability Principle 4: In the sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.
Production: *production by suppliers of sub-components & materials, as well as production of products at the own company.*	9	***i)** Only recycled materials are used, with no metal emissions and all scrap metals are recycled into pure fractions. **ii)** Only renewable energy sources are used in the production processes and the energy usage has an efficiency rate of 100%..*	9	*No emissions and waste products from production sites (even at suppliers) contain substances in the SIN-list.*	9	*No production used for product or components cause physical degradation of Nature.*	9	*No risk today or in the future for unhealthy and unsecure working environment in production. There is no violation of the ten principles of the United Nations Global Compact and the recommendations for the main social categories described in ISO 26000 are followed.*
	6	*i)Recycled metals are used and over 50% of the scrap metals are recycled into pure fractions. ii) A majority of the energy sources used in the production processes are renewable and an energy plan is followed with actions for energy usage reduction.*	6	*A phase out/substitution plan is followed for those chemicals/materials used that is included in the SIN-list.*	6	*Actions from a reduction plan are implemented systematically for reducing clean water usage and waste & spill from production processes.*	6	*A safety plan is followed for reducing injuries, occupational diseases, lost days and absenteeism in the production during a year.*
	3	***i)** Recycled metals are used in production, but it is not known to what extent there are emissions and scrap of metals from production. **ii)** Renewable energy sources are used in the production processes (still some are fossil based), and the efficiency rate of the energy usage is measured.*	3	*There are no emissions and waste products from production sites that contain substances in the REACH-candidate list, but chemicals/materials included in the SIN-list occur.*	3	*Recyled water is used and a reduction plan for how to reduce the waste & spill from production is implemented.*	3	*There are no workrelated fatalities in the production but there are injuries, occupational diseases, lost days and absenteeism in the production during a year.*
	1	***i)** No recycled materials are used and/or it is not known to what extent there are emissions and scrap metals from production. **ii)** Only fossil based energy sources are used in the production processes.*	1	*There are emissions and waste products from production sites that contain substances in the REACH-candidate list.*	1	*Only clean water is used for production and there are unknown amounts of waste & spill from production.*	1	*There are workrelated fatalities in the production and no information regarding totalt number of injuries, occupational diseases, lost days and absenteeism in the production during a year.*
	0	***i)** Do not know if and how much recycled materials that are used. Do not known the amount of emissions and scrap metals from production. **ii)** Do not known if and how much renewable energy sources used in the production processes and if the energy usage in the production processes are efficient.*	0	*It is not known if there are emissions and waste products from production sites that contain substances in the REACH-candidate list.*	0	*Do not know if and how much is used of clean water for production and/or the amounts of waste & spill from production.*	0	*Do not know if there is a risk today or in the future for unhealthy and unsecure working environment in production.*

Figure 4.4: Current Compliance level for Production life cycle phase, based on SCI matrix developed by Hallstedt (2014).

5 Analysis and Discussions

This chapter presents discussions and analysis of results obtained and correlating with literature findings.

5.1 Interviews

The motive of the interviews was to identify the prevailing gaps for sustainable development and to know the sustainability approach in GKN. From the interviews results, sustainability initiatives listed can be interpreted as GKN's small steps towards sustainability. The environmental goals and the efforts taken towards achieving these goals can be considered as worth contributing to sustainability. But it was evident that the initiatives and goals are not realized and aligned with strategy and goals of organization. It is because of the reason; there is no sustainability strategy in any departments or whole of GKN. Also, many interviewees commented that the word "sustainability" is not used in GKN. Altogether, it conveys the fact that there is a lack of communication and appreciation of sustainability values within GKN.

Support from higher management is not as required was also one of the common feedback. Zhu and Sarkis (2004) argue that senior management's commitment is basic foundation for successful implementation of sustainability practices and bring better performances. Cordano, et al. (2000) mention that training supervisors in environmental awareness and sensitivity is an important approach to ensure that sustainability thought is encouraged and performed in lower levels of organisation. Also, Kitazawa and Sarkis (2000) mention that employees' roles may be seen as "hands-on" contributions as they are the closest to the sources of pollution and they probably know the most about pollution and waste occurring along the manufacturing processes, hence it is important to close this gap in GKN and to include every department to be a part of sustainability work along with cooperation between management levels. Ramus and Steger (2000) claim that, providing incentives or awards to supervisors for sustainability achievements are also one of the ways to bring engagement from employees.

Also we can see the challenges realized are more generic, but it should be taken of high importance and it is appropriate to work through enforcing sustainability values. Wilson, et al. (2007) suggest that a **"***'green champion' should be employed to co-ordinate the process and encourage action".* And so**,** it is essential to form a sustainability focus group and integrate into all levels, through which it is ensured that sustainability is implemented and followed in GKN.

Another interesting fact is there is a huge gap between sustainability research work and actual operations carried out in GKN. This was understood when many departments did not comment or refer to the research work in GKN about sustainability. . It was common opinion that GKN's research should focus more aligning daily operations to sustainability, which is a valuable point and it should be taken into consideration by higher management.

GKN's values and the main principles and codes of the GKN PLC consist of the sustainability principles but the interviewees were not aware of the principles and neither it was present in internal communication. Communication about sustainability values or efforts are not present in the goals of communication department and this is the main obstacle as internal communication can improve sense of responsibility and spreading of sustainability knowledge.

5.2 Benchmarking

From the reports studied, it was perceived that that SKF has a strong sustainability platform. They have a strategy with respect to environmental, business, community and employee care, clearly stated future goals and continuous development and practicing of sustainability methods and system.

GE's sustainability report document gives a whole picture of commitment towards sustainability and their serious efforts which will serve as an inspiration for other companies. *Ecomagination* and *Healthymagination* program of GE is worth mentioning as it precisely focus and set up goals by segregating three pillars of sustainability. SKF and GE have focused sustainability goals and commitments and they constantly monitor and measure their performance. They continuously develop new methods and products that foster sustainability and involve in institutional programs that helps to set guidelines and principles for practicing sustainability and focus for future.

From, MTU´s sustainability report it is clear that the company put efforts in sustainability and there are concrete evidence of how the company have brought down sustainability to a more operational as well as local level. For instance, they have an innovative water system to reduce water consumption and production sites are using renewable energy and in general their production sites are designed to reduce the environmental impact, such as solar panels and heat exchanger to reduce energy consumption and these initiatives are a result from different sustainability programs where environmental goals are translated into practice.

GE as well as SKF communicates sustainability to high extent in relation to the topics that were compared in this analysis. As an OEM, GE highlights sustainability importance and show responsibility through their efforts. GE as well as SKF has clear goals related to sustainability that is supported by clear strategies including specific programs and initiatives within the area of sustainability. Equally GKN has goals but these goals are not supported in the sense of focused groups or external institutional involvement to the same extent as the other companies studied. In GKN there is sustainability indicators stated but in contrast to SKF these goals are not translated into daily practice. For instance, in SKF a monitoring system is used to visualize environmental indicators on the production floor. This initiative was developed since other standards such as LEED do not consider production operations. Since the result of this comparison only is based on the annual reports of the companies, it might be that GKN works with sustainability but do not promote it the same extent as the other companies. In other words it is possible that GKN is lacking in their communication about this topic.

"…green advertising approaches such as issuing environmental reports developing public relations by sponsoring environmental interest groups and launching marketing campaigns with a focus on the eco-friendliness of products can be useful for manufacturers to gain legitimacy and environmental reputation (Wong, et al., 2013).

If GKN could realize the value of a green manufacturing image, efforts could be done to highlight their current environmental activities in terms of putting a new dimension on their current sustainability report and improve communication internally about this topic. A question that emerged when compared the sustainability promotional efforts between these companies was; why does GKN not review the company's performance in the same manner as the other companies in their annual report? Desai and Gupta (1996) state that; "In publicizing their environmental actions, enterprises are hesitant about the potential risk of triggering an unwanted attack and attention from environmental

interest groups or competitors questioning the effectiveness of organizational initiatives, or the intention behind their environmental actions".

Ecologically sustainable organizations promote values of environmental protection and sustainable organizational performance using a variety of methods, including written communications, environmental-improvement activities, and educational activities, all of which illustrate a strong commitment to ecological sustainability (Starik & Rands, 1995).

As recommendations, in the case of GKN, while other companies take advantages of improving their image in terms of sustainability, there is potential for GKN to increase communication about their current sustainability efforts. Since the public awareness about this topic as well as customers and supplier requirements has increased, this report could awake discussions within GKN if value could be created as an outcome of an improved image.

It was understood from benchmarking studies that companies have started to adopt sustainability in higher extent at all levels, especially on operational level, and started reporting on operational performance too. In the aerospace industry, most focus have been put on developing products that contribute to less emissions during usage phase, which is the most critical point in the product lifecycle. But now companies´ have started reporting on environmental performance for specific operations in their annual reports and started presenting their sustainability practices and connection to overall strategy.

5.3 Concept Map

From the results, it could be concluded that in GKN the employees have knowledge in the three pillars of sustainability but the main focus is on the environmental and economic dimensions and less focus on the social and institutional dimensions. Further, to evaluate relation of sustainability knowledge to the sub categories as Environment, Resource scarcity, Social impact, Values, Future (temporal), Unbalances, Technology, Economy, Education, Actors and stakeholders, it is seen that technology is related most. This could be due to the reason that, most of the workers discuss about technology improvement and relate to solve sustainability issues.

The purpose of concept maps is to give the company an understanding about the gaps of sustainability and help the company to achieve higher alignment between sustainability initiatives and employees involvement. For instance, if the employees are aware of how the social impact could affect the company's sustainable development, it ensures that the employees understand the company´s values and codes regarding social sustainability. In addition the workshops that were conducted to perform the concept maps created interest among the participants about this thesis work resulting in discussions about the topic.

As mentioned earlier in this thesis work, Mathiyazhagan, et al. (2012) argue that low awareness about sustainability is a bottleneck for sustainability implementation as well as negative employee attitude is seen as hinder in the same sense. Therefore, the authors of this thesis mean that the result of the concept maps provides the company with information about the current level of awareness among the employees and gives indications to what extent sustainability has been communicated. GKN PLC has documented principles covering economic, environment and social aspects. However, these principles have not been communicated to higher extent in GKN aerospace. So, to increase understanding it could be the mission of each department to break down these principles into more concrete values to follow within different functions of the company.

Concept maps led to discussion among the participants in the workshop and an overview about how employees relate to various concepts. However the way people think about sustainability may not be exactly correct reflected on a paper while asking them to create a mind map about the topic "What is Sustainability for you?", still the picture of organisation could be provided approximately. The authors of this thesis have been able to highlight the topics for the management because there are potentials to improve internal communication in the company.

5.4 Evaluation using Criteria matrix:

5.4.1 Life Cycle Phase: Material source

Analysis from various results obtained and the suggested future level of compliance for the material source life cycle phase is discussed in the following section; The future level of compliance for Material source and Production Lifecycle phase is presented in Figure 5.1 and Figure 5.2 in page 50.

First Principle:

Since the measurements were not possible relating to the principle, it was hard to see if LPT case has risk and conflict materials. It is important to admit the fact about the lack of knowledge about risk and conflict materials, which should be the immediate focus in material and product development.

Future level of Compliance:

The next compliance state GKN should achieve is level 3 which means "No conflict materials/metals are used but other risk materials are used". To reach this level, GKN should focus on listing the conflict materials that are being used through the help from GRANTA database and related sources. This could be accomplished;

1) By developing a substitution plan focusing on the future market requirements and availability of materials.
2) Through taking responsibility of recycling the conflict materials and risk materials.

Second Principle

Since the measurements suggest that there are chemicals in REACH list and SIN-list, it is important for GKN to understand and forecast the legality and permissions of using these chemicals and find the valid replacements accordingly.

Future level of Compliance:

Next compliance level GKN should achieve is 3 and corresponding compliance statement is "No usage of materials that contain or result in chemicals that are included in the REACH-candidate list, but chemicals/materials included in the SIN-list are used". GKN should start immediate steps to find alternatives for REACH list chemicals by following a strategic plan of listing the most hazardous chemicals and focus on basis of priority. Priority could be decided on the basis of future requirement, company policy, availability etc. The thesis authors have developed a model of a replacement database as in Table 5.1.

Table 5.1: Suggested Model of Replacement plan

S.No	Chemical name	Hazardous level	Importance level	Replacement by	Initiatives	Remarks
1	XYZ	5-highly dangerous	1-high priority	2015		
2	ABC	5	2	2015		
3	DEF	4	3	2017		
4	GHI	3	4	2018		
5	……	…..	….	….		

Third Principle:

Future level of Compliance:

The next compliance level should be three and corresponding compliance statement is "Have a substitution plan for raw materials & chemicals and/or its manufacturing sites that cause physical damage to Nature". Company should start implementing a regulation based on this criterion to suppliers and identify the suppliers who are not compliant to the regulations. The substitution plan should be developed for those materials and chemicals. This should be implied in the strategy for supplier regulations.

Fourth Principle:

Future level of Compliance:

The next level of compliance that should be reached is 3 where the compliance statement is "i) No usage of conflict materials for product components and/or its production is used. ii) Do not know if there is a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production". First step is to make the detailed regulations on the basis of these criteria and standardise these regulations with suppliers on cooperation and communication or finding alternative suppliers.

5.4.2 Life cycle Phase: Production

Analyses from various results obtained and the suggested future level of compliance for the production life cycle phase are discussed in the following section;

First Principle:

Future level of Compliance:

Although GKN is in level 6, which is almost the best level, there is always scope for improvement and standardisation in this level. This could be performed by focusing on calculating and improving the energy efficiency to 100%. There are no currently available methods to measure the energy efficiency of machines, heating systems, plant etc., there should be systems implemented for visualizing and tracking the energy consumption and efficiency for each resources. This could help GKN to improve on level 6 and reach level 9 in a period of time. Also, GKN uses 50 to 80% of recycling materials for forging of LPT case which is not measured accurately. Hence it is valuable for GKN to measure the recycling and virgin material ratio and increase over the years. To reach next

level, it is required to use only recycling materials for production which could be accomplished slowly in further years.

Second Principle:

Future level of Compliance:

Since GKN is in compliance level 1 and the future level of compliance should be 3. It should be first priority to identify on chemicals and associated material wastes that are in REACH Candidate list and eliminate the same. But, there is always scope for other improvements and they could be:

1) Finding effective ways of waste management to reduce cost, space.
2) Study and apply various waste disposal methods
3) Constant check of external regulations and customer requirements.

Third Principle:

Future level of Compliance:

The next compliance level to be attained is 9 for which the statement of compliance is ”No production used for product or components cause physical degradation of Nature”. This statement has a huge meaning and it could be interpreted in different ways as follows,

1) 100% recycled water for production
2) No material wastes from production wastes/100% material efficiency
3) Recycling all the material and chemical wastes
4) No landfill wastes

It is essential to develop targets and action plan should towards achieving this compliance level.

Fourth Principle:

Future level of Compliance:

Although current level is extremely good for GKN, safety audits and processes could be improvised according to feedback from employees and respect to technology changes.
The next compliance level to be attained is 9 and compliance statement is “No risk today or in the future for unhealthy and unsecure working environment in production. There is no violation of the ten principles of the United Nations Global Compact and the recommendations for the main social categories described in ISO 26000 are followed”. This means that GKN should start following proactive measures for safety of employees in production and focus on employing practices aligning to ten principles of United Nations Global Compact. This is a slow process and requires immense efforts to reach level 9, but it is important to check and standardise the right methods for safety and health.

Current level of Compliance | Future level of Compliance

	Sustainability Principle 1	Sustainability Principle 2	Sustainability Principle 3	Sustainability Principle 4
9	No risk-materials used according to raw material lists.	No materials for products and/or production used that contain or result in emissions of substances included in the SIN-list.	No use of raw materials & chemicals and/or its manufacturing sites that cause physical degradation of Nature.	No materials and chemicals used that cause violation of human needs.
6	Move towards risk-free material usage with high natural availability, high commercial availability, high maturity of materials and processes, materials with low competition of this material and good enough number of potential suppliers.	A phase out/substitution plan is followed for those chemicals/materials used that is included in the SIN-list.	Have completed more than 50% of the substitution plan for raw materials & chemicals and/or its manufacturing sites that cause physical damage to Nature.	**i)** No usage of conflict materials for product components and/or its production is used. **ii)** Have a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production.
3	No conflict materials/metals are used but other risk materials are used.	No usage of materials that contain or result in chemicals that are included in the REACH-candidate list, but chemicals/materials included in the SIN-list are used.	Have a substitution plan for raw materials & chemicals and/or its manufacturing sites that cause physical damage to Nature.	**i)** No usage of conflict materials for product components and/or its production is used. **ii)** Do not know if there is a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production.
1	Conflict materials and other risk materials used in the alloys today	Materials that contain or result in chemicals that are included in the REACH-candidate list are used.	All raw materials & chemicals and/or its manufacturing sites used, cause physical degradation of Nature.	**i)** Conflict materials for product components and/or its production is used. **ii)** Do not know if there is a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production.
0	Do not known if and what risk materials that are present in the alloys today	Do not known if materials or chemicals used is included in the REACH-candidate list.	Do not know if or which of the raw materials & chemicals and/or its manufacturing sites used, that cause physical degradation of Nature.	**i)** Do not know if conflict materials for product components and/or its production is used. **ii)** Do not know if there is a certificate showing that the laws and regulations are followed in the country that extract raw materials or produce chemicals used in the company's product/production.

Figure 5.1: Current and future compliance level for Material Source Life cycle phase

	Sustainability Principle 1	Sustainability Principle 2	Sustainability Principle 3	Sustainability Principle 4
9	i) Only recycled materials are used, with no metal emissions and all scrap metals are recycled into pure fractions. ii) Only renewable energy sources are used in the production processes and the energy usage has an efficiency rate of 100%..	No emissions and waste products from production sites (even at suppliers) contain substances in the SIN-list.	No production used for product or components cause physical degradation of Nature.	No risk today or in the future for unhealthy and unsecure working environment in production. There is no violation of the ten principles of the United Nations Global Compact and the recommendations for the main social categories described in ISO 26000 are followed.
6	i)Recycled metals are used and over 50% of the scrap metals are recycled into pure fractions. ii) A majority of the energy sources used in the production processes are renewable and an energy plan is followed with actions for energy usage reduction.	A phase out/substitution plan is followed for those chemicals/materials used that is included in the SIN-list.	Actions from a reduction plan are implemented systematically for reducing clean water usage and waste & spill from production processes.	A safety plan is followed for reducing injuries, occupational diseases, lost days and absenteeism in the production during a year.
3	i) Recycled metals are used in production, but it is not known to what extent there are emissions and scrap of metals from production. ii) Renewable energy sources are used in the production processes (still some are fossil based), and the efficiency rate of the energy usage is measured.	There are no emissions and waste products from production sites that contain substances in the REACH-candidate list, but chemicals/materials included in the SIN-list occur.	Recyled water is used and a reduction plan for how to reduce the waste & spill from production is implemented.	There are no workrelated fatalities in the production but there are injuries, occupational diseases, lost days and absenteeism in the production during a year.
1	i) No recycled materials are used and/or it is not known to what extent there are emissions and scrap metals from production. ii) Only fossil based energy sources are used in the production processes.	There are emissions and waste products from production sites that contain substances in the REACH-candidate list.	Only clean water is used for production and there are unknown amounts of waste & spill from production.	There are workrelated fatalities in the production and no information regarding totalt number of injuries, occupational diseases, lost days and absenteeism in the production during a year.
0	i) Do not know if and how much recycled materials that are used. Do not known the amount of emissions and scrap metals from production. ii) Do not known if and how much renewable energy sources used in the production processes and if the energy usage in the production processes are efficient.	It is not known if there are emissions and waste products from production sites that contain substances in the REACH-candidate list.	Do not know if and how much is used of clean water for production and/or the amounts of waste & spill from production.	Do not know if there is a risk today or in the future for unhealthy and unsecure working environment in production.

Figure 5.2: Current and future compliance level for Production Life cycle phase

Maturity level of company

Referring to the maturity level explained in section 2.3 and Table 2.2 and from the understanding of above mentioned discussions it can be considered as GKN is in the level of agnostic and it is appreciative if GKN relate and improve their efforts to be in supportive level.

6 Sustainability Indicators Framework

This chapter presents a model of sustainability indicators framework which the thesis authors developed to emphasize the importance of using measures for sustainable development.

6.1 Purpose

When GKN will follow a sustainability based strategy, it is important to measure the progress which will help the management visualize the achievements and decide on appropriate future actions. It is valuable for company to provide information about their sustainability performances to the potential customers and stakeholders. Also, from the interviews, it was understood that there is no established KPI´s with respect to sustainability. Hence the thesis authors identified the need for a detailed set of sustainability indicators. This is only an example model and it could be modified according to the sustainability strategy of organisation.

6.2 Sustainability Indicators Framework

As mentioned before, Sustainability indicators can be defined as ”Information used to measure and motivate progress towards sustainable goals” (Veleva, et al., 2001). A sustainability indicator framework includes a set of indicators covering all three dimensions of sustainability and defined at different levels of organisation. Conceptual step framework proposed by Arenaa, et al. (2009) mentioned in section 2.9 could be used in GKN for the below presented indicators.

Since GKN already has a set of criteria for sustainable product design, this was used as a base for developing indicators. Also, literature review was performed to identify and consolidate a set of indicators that will help the organisation in the measuring process. The literatures include the articles mentioned in section 2.9. As mentioned before, the set of criteria is based on socio ecological dimension and indicators were also extended in economic dimension by referring to common available indicators in the literature. The literatures studied include Veleva, et al., 2001; Olsthoorn, et al., 2001; Feng & Joung, 2009; Moss & Grunkemeyer, 2007; Arenaa, et al., 2009; Joung, et al., 2012; Winroth, et al., 2012. The thesis authors mean that the indicators mentioned in this chapter are very basic and common to all organisations and should use in the process of sustainable development.

The model used in Figure 2.6 is used to categorize and develop the indicators. In general, the three dimensions of sustainability are economic, environmental and social. Different aspects of each dimension are identified through the various factors namely strategy, stakeholder decisions, regulations, norms, type of product and processes etc., Here the aspects are identified through the set of criteria in the criteria matrix and the related indicators were discussed with stakeholders in GKN to study the relevance and usage of indicators.

Since sustainable development is considered as corporate responsibility, sustainability indicators should be controlled together by corporate responsibility and higher management in GKN. The target values of every indicator should be set and clearly specified for every annual year. Corresponding department becomes responsible for measuring the indicators and for taking relevant actions.

As an additional suggestion, a sustainability database should be maintained where the values of indicators are filled in and the progress is tracked on a regular basis. The sustainability indicators frameworks for three sustainability dimensions are as follows:

6.2.1 Environmental Indicators:

The environmental indicators should be controlled by the environmental department in GKN. Environmental department could have an internal indicators database and work with corresponding departments to keep a track of values and demand for necessary actions and improvements. GKN has Data collection system tool where the energy consumption, chemicals usage and associated CO_2 emissions etc., are calculated and tracked. This shall be modified and used for the sustainability indicators. Based on the three ecological principles, seven different aspects for environmental dimension were identified and they are as follows:

1. Material Use
2. Energy Use
3. Water Use
4. Waste
5. Emissions
6. Environmental legal and standard compliance
7. Product

The indicators under each aspect of environmental dimension are explained in Table 6.1.

Table 6.1: Framework of Indicators for Environmental Dimension

Aspect	Indicators	Unit	Responsible for measure	Control of Measure
Material Use	Total Material usage	Tonnes per unit of sales	Production and procurement Manager	Corporate responsibility and Environmental Manager
	Scrap rate	% of total material usage		
	Total chemical usage	Tonnes per unit of sales		
	Amount of material recycled	Tonnes per unit of sales		
	Amount of recycled materials used	Tonnes per unit of sales		
Energy Use	Use of renewable energy	% of total energy resources	Facility Manager	
	Energy use	kWh per unit of sales		
	Energy efficiency	%		
Water Use	Total water consumption	m^3		
	Recycled water	% of total water consumption		

Waste	Total solid waste	Tonnes per unit of sales	Production Manager and Facility Manager	
	Weight of non-hazardous waste	Tonnes per unit of sales		
	Weight of hazardous waste	Tonnes per unit of sales		
	Weight of production waste to landfill	Tonnes per unit of sales		
Emissions	Total CO_2 Emissions	Tonnes per unit of sales	Facility and environmental Manager	
	Total emissions of ozone depleting substances	Tonnes per unit of sales		
	Total emissions causing acid rain (NO_xetc.,)	Tonnes per unit of sales		
	Discharge of chlorinated VOCs	Tonnes per unit of sales		
	Discharge of VOCs (Volatile Organic Compounds)	Tonnes per unit of sales		
Environmental legal and standard compliance	Environmental accidents	Number	Environmental manager	
	Chemicals in SIN list	% of Total Chemicals used		
	Materials in SIN list	% of Total Materials used		
	Environmental standards for supplier (ISO 14001)	Yes/No		
Products	% of products designed for Recyclability	% of Total products	Product development	
	% of products that are designed for Remanufacturability	% of Total products		
	% of products designed for reduced fuel consumption	% of Total products		
	% of products designed for reduced weight	% of Total products		

6.2.2 Economic sustainability Indicators

The economic indicators that are relevant for progress of organisation are divided into eight aspects as following:

1. Business and finance
2. Employees

3. Customer
4. R&D
5. Production operation
6. Supplier
7. Technological advancement
8. Product

Indicators under each aspect for economic dimension are provided in Table 6.2.

Table 6.2: Framework of Indicators for Economic Dimension

Aspect	Indicators	Unit	Responsible for measure	Control of measure
Business and finance	Return on Investment	SEK	Finance Manager	Corporate responsibility and Finance Manager
	Profitability index			
	Market Share	%		
	Sales growth	%		
Employees	Employee Costs	SEK/per unit of sales	Human resource Manager	Corporate responsibility & Human resource Manager
	Investments in Employee Development	SEK/per unit of sales		
Customer	Number of customer complaints /returns	Number/per unit of sales	Customer relations manager	Corporate responsibility & Customer relations manager
	Customer communication and relation/satisfaction factor	Index number /%		
R&D	Value of investments in sustainable development	SEK/per unit of sales	R&D Manager	Corporate responsibility & R&D Manager
	Value of investments in EHS(Environment, health and safety)	SEK/per unit of sales		
	R&D expenditure	SEK/per unit of sales		
Operations	Operating costs	SEK/per unit of sales	Operations Manager	Corporate responsibility & Operations Manager
Supplier	Fraction of suppliers without environmental, health and safety violations	%	Supplier Quality Manager	Corporate responsibility & Supplier Quality Manager

Technological advancement	Innovative concepts and contributions	Number	R&D Manager	Corporate responsibility & R&D Manager
	New technology development/adaptation for production and product development	Number		
Product	Number of new products designed for sustainability	Number	R&D Manager	Corporate responsibility & R&D Manager

6.2.3 Social Sustainability Indicators

The social indicators that are relevant for social development are divided into seven aspects as following;

1. Health and safety focused on work place
2. Education and training
3. Labour-management relations
4. Stakeholders
5. Diversity and equal opportunity
6. Human capital
7. Community

Indicators under each aspect for economic dimension are provided in Table 6.3.

Table 6.3: Framework of Indicators for Social Dimension

Aspect	Indicators	Unit	Responsible for measure	Control of measure
Health and safety focused on work place	Total No. of Accidents	Number/per year	Health and Safety Manager	Corporate responsibility and Health and Safety Manager
	Absence due to injuries or work related illness	Number of days/year		
	Elimination of hazardous work places	Number of places/year		
	Number of safety training and programs	Number of programs/year		
	Compliance with ten principles of United nations Global compact	Yes/No/In progress		
	Compliance with ISO45001	Yes/No/In progress		
	Compliance with ISO 26000	Yes/No/In progress		
Education and training	No. of training hours per employee	Hours/employee	Human Resource Manager	Corporate responsibility & Human resource Manager
	Participation ratio in improvement groups	Number		

Labour-management relations	Rate of temporary workers (Number of temporary/Number of permanent)	%	Human Resource Manager	Corporate responsibility & Human resource Manager
	Rate of employees that are share holders	%		
Stakeholders	Organization openness to Stakeholder involvement	%		
	Suggested improvements from employees	Number		
Diversity and equal opportunity	Male to female ratios	Ratio		
	Involvement of Cross functional teams for improvements			
	Non-discrimination Gender/Age/Ethnical/Sexual	Yes/No		
Human capital	No. of new employees per year	Number		
	Employee satisfaction rate	Number		
	Support for employee physical activity, Health care and medicine	Yes/No		
	Employee turnover	Number		
	Competence Improvement	Rate (%)		
Community	Number of community outreach activities	Number	Corporate responsibility Manager	Corporate responsibility Manager
	Non-compliance with laws	Number		

6.2.4 Operational level indicators:

An attempt to develop operational level indicators model was made to indicate GKN the relevance of the same. It is understood that Operational level indicators should be aligned to overall indicators. This is important to ensure sustainability engagement from all levels of organisation. Since LPT case production was studied closely, operational level indicators framework is developed for same. Below Table 6.4 provides a model clearly specifying the goals and associated indicators and specifications. This model was adapted from literature (Winroth, et al., 2012). This detailed specification is easy to understand the responsibilities. The relevance and usage of the below mentioned indicators was discussed with production department responsible persons.

Table 6.4: Production level indicator framework and specification details

Goals	Production Lead time reduced by x%	Improving OEE by y%	Inventory reduced by z%
Indicator title	Lead time	OEE (Overall Equipment Effectiveness)	Total inventory
Purpose	To monitor the production flow and improve the improvement actions to reduce lead time	To monitor equipment performance and to identify improvement actions	To monitor the inventory quantity and to identify improvement actions to reduce
Relates to	Machining time, waiting time, set up time, inspection time etc.,	Scrap rate, speed rate, downtime rate	Work in process inventory, incoming inventory, buffer and delivery stock
Formula	Total lead time from the incoming of machined material till the delivery	(Ideal cycle time) × (No. of quality approved items) / (Planned production time)	
Frequency of measurement	Every month	Everyday	Everyday
Frequency of review	once a month	once a month	once a month
Who measures?	Production leader	Operator	Production leader
Source of data	Machining records	Disturbance data (planning system), quality records	Inventory records
Who owns the measure?	Production manager	Production manager	Production manager, procurement and supply manager
Who acts on the data?	Production leader, manager, maintenance	Operator, maintenance, operations management	Production leader, manager, maintenance

This could be performed for other indicators of production as:

1) Scrap rate,
2) Delivery Schedule adherence
3) Productivity
4) Process reliability
5) Energy efficiency
6) Utilization of Man labour
7) Number of break downs/disturbances

When this indicators framework is used, it is convenient to visualize the progress of sustainable development in GKN and to integrate all the departments together by employing specific responsibilities. This will work as an efficient way of understanding the sustainability inside the organisation and to communicate externally to improve the sustainability image of GKN.

7 Guidelines for Sustainable development of GKN

For sustainable development, this thesis work aims to establish guidelines for GKN. These guidelines were developed by extensive literature review and supported through the results based on interviews with stakeholders, benchmarking, concept maps and evaluation of LPT case using criteria matrix. These guidelines are developed to be followed step by step in order to effectively understand the values of each procedure.

7.1 Procedure to implement Sustainable development in GKN

The nine steps procedures to implement sustainable development in GKN are as follows;

1. Improve awareness about the three pillars of sustainability and its values in GKN
2. Identify barriers for the company in their sustainable development
3. Develop strategy and policies for sustainability
4. Set up Strategic Goals and Break down the Goals into different operation levels in GKN
5. Develop indicators for measuring the targets and set up measurement system to monitor the progress towards the Goals
6. Align the initiatives to attain the Goals
7. Monitor progress and communicate the results internally and externally to all stakeholders
8. Review indicators, strategy and goals
9. Develop a culture of sustainability practices among all stakeholders

Below flowchart in Figure 7.1 presents the above mentioned nine steps that GKN could follow to implement sustainability in GKN.

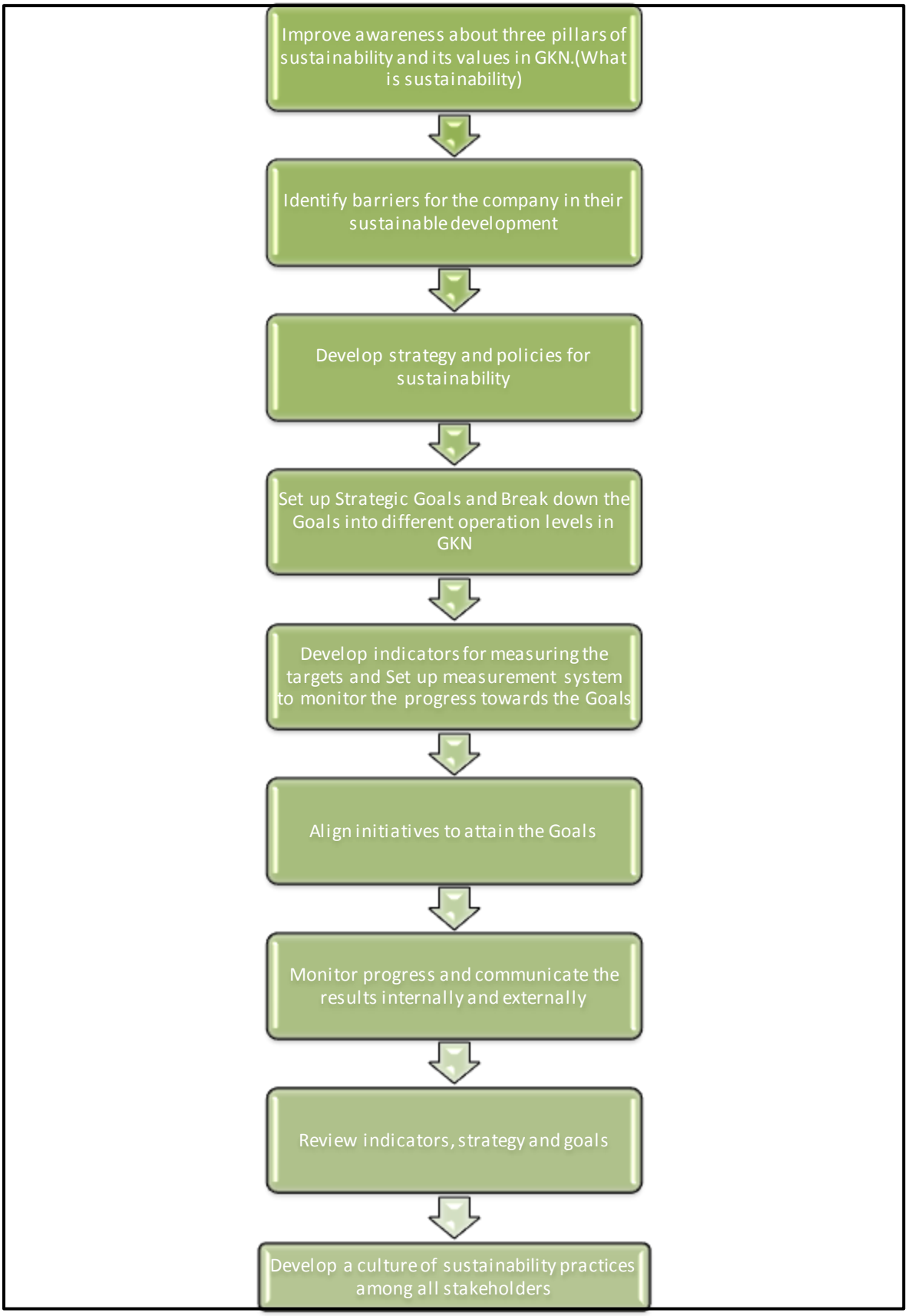

Figure 7.1: Guidelines for sustainable development of GKN

Since GKN could adapt the guidelines, brief explanation about each guideline is provided for understanding. Explanations of each step in the guideline are as follows:

7.1.1 Improve awareness about the three pillars of sustainability and its values in GKN

The first and foremost step for any industry towards sustainable development is to ensure that the three main pillars of sustainability and its values are recognized among all stakeholders. Sustainability is a wide concept and there is a higher chance, it could be interpreted wrong if it is not communicated clearly. Interviews in GKN also proved the same, because most of interviewees perceived sustainability as only climate change, waste separation, waste recycling etc., the thesis authors had to explain the meaning of sustainability regards to industrial perspective. Also, concept map results showed that the most of the employees have knowledge about environmental and economic dimension and related most of the concepts to the same. GKN has researchers doing study about sustainability and developing criteria matrix to implement sustainability values in product design stage so that the whole supply chain is sustainable. But this knowledge is only in research level and it needs to be integrated into operational level.

This could be performed through workshops about sustainability values, small activities, movies, advertisement boards, guest lecture from industry and universities could be different ways to spread knowledge about sustainability values.

Stakeholder Analysis

When spreading knowledge about sustainability and sustainable development in the company, it is also important to understand the interest of various stakeholders and their role for sustainable development process. The stakeholder analysis is required for the company when starting their participation for sustainable development. Stakeholder analysis should start with identifying groups that are affected by the activities of company. They include shareholders, customers, employees, community, external institutions etc., Next step includes to identify the interests of every stakeholder towards this development. Concluding every need of stakeholders and normalizing it to the current position of company will help the organization to understand the roles and responsibilities towards sustainable development.

7.1.2 Identify barriers for the company in their sustainable development

Identifying the barriers that have influence on the company´s ability to drive sustainability implementation is an important step. Discussion and understanding of these barriers gives a clear vision about the requirements for developing strategy. For example, the barriers include, managers think sustainability is important but still short-term goals are prioritized. The aim of this thesis work is to identify LPT´s improvements potential, but as a first step it is relevant to understand the company's constraints in sustainable development. Table 7.1 is established visualizing the barriers that have been identified through interviews, concept maps, and benchmarking and literature studies.

Table 7.1: Barriers for GKN's sustainable development

Barriers for sustainable development	Source of identification	Sustainability Issues	Requirement
Incremental cost of putting in an environment improvement	Interviews, (Wycherley, 1999)	Environmental initiatives deviate from core business Hard to connect to customer value	Align environmental initiatives to strategy Motivate each initiative according to strategy and goals.
Lack of connection between environmental efforts and business objectives	Interviews	Lack of executive management support	Clear and communicated Strategy Improved understanding about the business impact
Lack of sustainable approach	Interviews, benchmarking	Short term thinking	Clear strategy towards long term goals. Identify long term values.
Communication	Interviews, benchmarking	Gap between research department and value for the company	Higher coherence Knowledge transfer
Low awareness	Interviews, Concept Maps	Less understanding about the company´s policy about sustainability	Communicate sustainability
Complex to measure and monitor the environmental practice of suppliers	(Morgan, 2006), (Mathiyazhagan et al., (2012)	Metrics misalignment, unsustainable suppliers	Make sure that suppliers are compliance with laws and regulations
Lack of top management involvement in adopting green practises	Interviews	Only financial aspects considered	Communicate initiatives from department level. Bottom up.

Design owned by customers	LPT Case	Less influence on design	Get design control, Cooperate with customers
Lack of effective environmental measure	(Rao & Holt, 2005)	No progress towards sustainable production	Establish/ introduce relevant measures according to strategy and goals

7.1.3 Develop strategy and policies for sustainable development

When the importance of sustainability values is understood and sustainability issues are identified, third step is to develop strategy and policies and set targets to achieve sustainable development. This is the most critical and important step and this helps in decision making and defines the future of organization. Board Members and senior management should take the commitment and responsibility for deploying strategies for organization.

Stakeholder involvement:

During benchmarking process, it was understood that GE, MTU and SKF perform materiality matrix method to understand and prioritize sustainability issues. Materiality matrix is a method to list the sustainability issues and opportunities relevant to the organization and assigning a priority for each issues based on stakeholder preference. The materiality matrix model is presented in Figure 7.2 (GRI, 2011). Hsu, et al. (2013) mention "Materiality analysis is an essential element for sustainability reporting and requires to follow a systematic evaluation framework or model to identify material issues". This should be performed by cooperation between corporate responsibility management and identified stakeholders. This will help as a way to understand and communicate about sustainability values and also to define strategy and goals for organisation. An example of MTU's Materiality matrix obtained from their 2012 sustainability report is presented below in Figure 7.3.

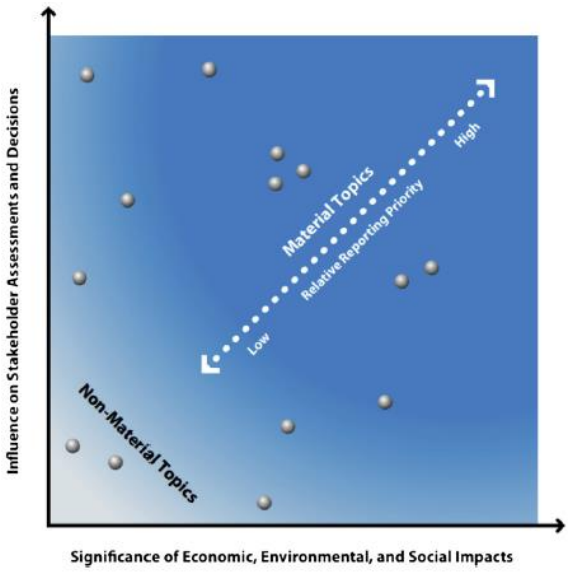

Figure 7.2: Materiality matrix model (GRI, 2011)

Figure 7.3: MTU's Materiality Matrix (MTU Aero Engines, 2013)

The issues identified from the materiality matrix are prioritised and lead to design appropriate sustainability strategy for the organization. Based on the current market requirements, strategy needs to be developed. For GKN, customers like GE, MTU have sustainability objectives defined and so, communication with the customers could help to define the roles of GKN towards sustainability and to figure out the initiatives to be taken. It is important for GKN to be proactive and align their goals to the objectives of customer.

Sustainability strategy

To start with, GKN PLC has already designed their codes and principles to work in sustainable manner. To take these codes and the identified sustainability opportunities together could be right way to design sustainability strategy. Through this, GKN ensure that their working codes and principles are referred and it can be assured that employee knows those values through the established strategy.

It is important to include sustainability principles to define the strategy. To perform that, criteria matrix is an efficient way as it considers all the four principles of sustainability which will provide as a way to identify the focus for GKN. For example, criteria used for evaluation of LPT case provided knowledge about focus on risk and conflict materials. This should be taken on high priority as the knowledge is lacking about the same. Similar opportunities for improvements were identified through using criteria matrix. Hence criteria matrix should also be the source of strategy definition and decisions. To combine all, Figure 7.4 presents the sources of defining the sustainability strategy for GKN organisation as;

1) GKN codes and principles
2) Sustainability criteria matrix
3) Issues and opportunities from Materiality matrix

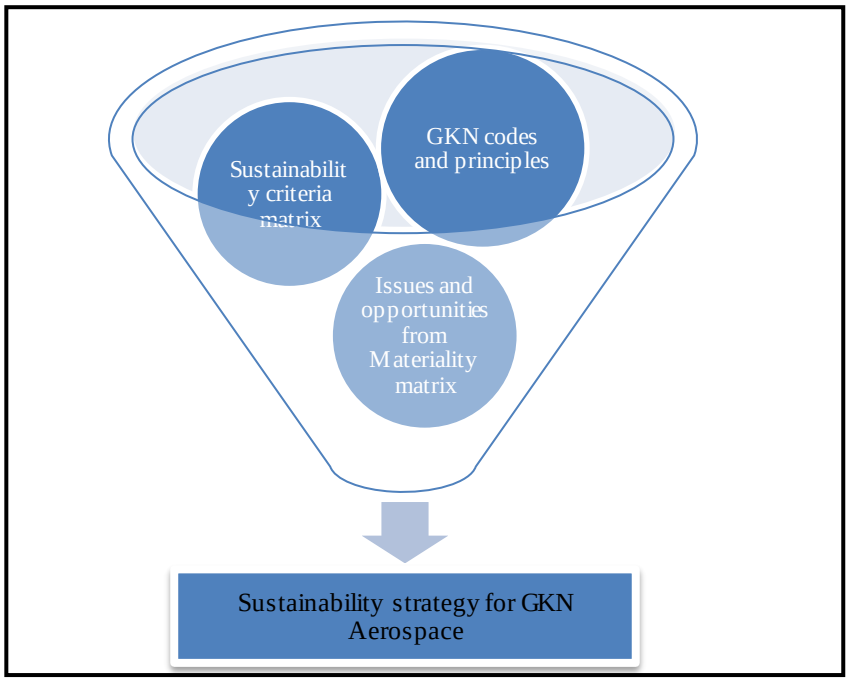

Figure 7.4: Sources for defining sustainability strategy for GKN aerospace

Wilson, et al. (2007) provide a checklist for efficient strategy and action plan, which is important to consider when strategy is developed. Board and senior management responsibility and complete association are essential to support and get the involvement of staff and commitment. Also, it is important to have multi-disciplinary department members and their views for an effective sustainability strategy and performance.

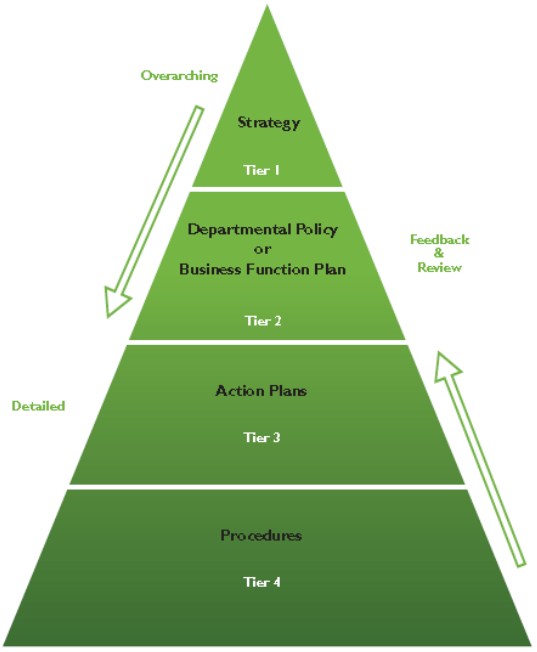

Figure 7.5: Sustainability strategy model (Wilson, et al. 2007).

Figure 7.5 clearly explain how the strategy should be integrated along the different levels namely, departmental policy or business, action plan and procedures (daily goals). It becomes more detailed when it goes down the levels and it should be reviewed and feedback should be provided to higher level to track if it is aligned with the strategy on a regular basis.

Also, one of the relevant points is to have a *sustainability champion/leader*. This leader take the complete responsibility of this development process and cooperates continuously with all management to take relevant actions and work according to define strategy and policies of organisation. One suggestion could be to move the environmental department higher in the hierarchy to control operational and product development departments and take decisions related to use of materials and chemicals type etc.

Short term and Long term Focus

As mentioned, one of the major barriers is short-term focus and so the strategy should compensate this by realising and understanding the short and long-term values for the organisation. For the reason that increased competitiveness on the market, pressures companies to satisfy customers in daily practices, sustainability success also requires short term and tactical decisions. Hence, it is important that long term goals on strategic level are aligned with goals on tactical level. The authors of this thesis mean that strategic decisions needs to be taken to catch market advantages under changing conditions, leading to increased focus on long term value of sustainability in all three dimensions. Accordingly in a time perspective, short-term value and long-term value could be categorized to distinguish between operational level and strategic level decisions and to clarify the relation between respective values. In order to understand the balance of short- and long term aspects, Figure 7.6 is presented below illustrating different dimensions of sustainable thinking; *Change through rethinking* and *Growth through reinventing* are related to long term aspects, while *Surviving by resourcing* and competing by refocusing are related to short term aspects.

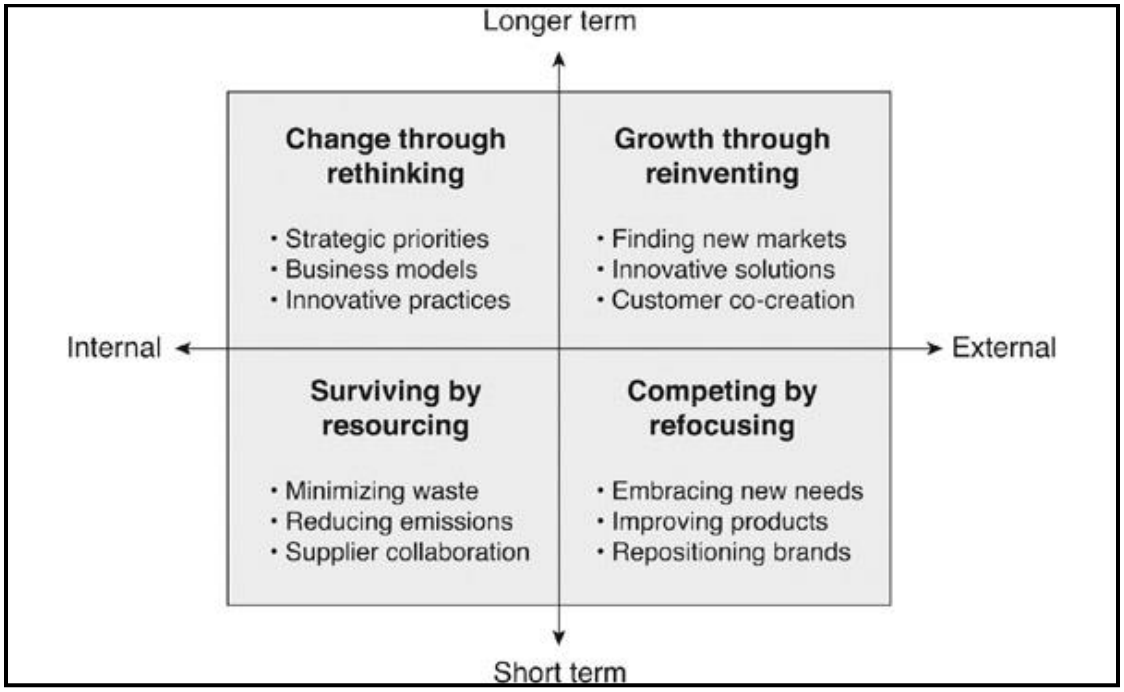

Figure 7.6: View on how short- and longer term could be balance to achieve profitable growth (Fisk, 2010).

To clarify alignment of short term and long term aspects, the flowchart in Figure 7.7 provides an example depicting the correlation between various short-term decisions and long-term strategic decisions.

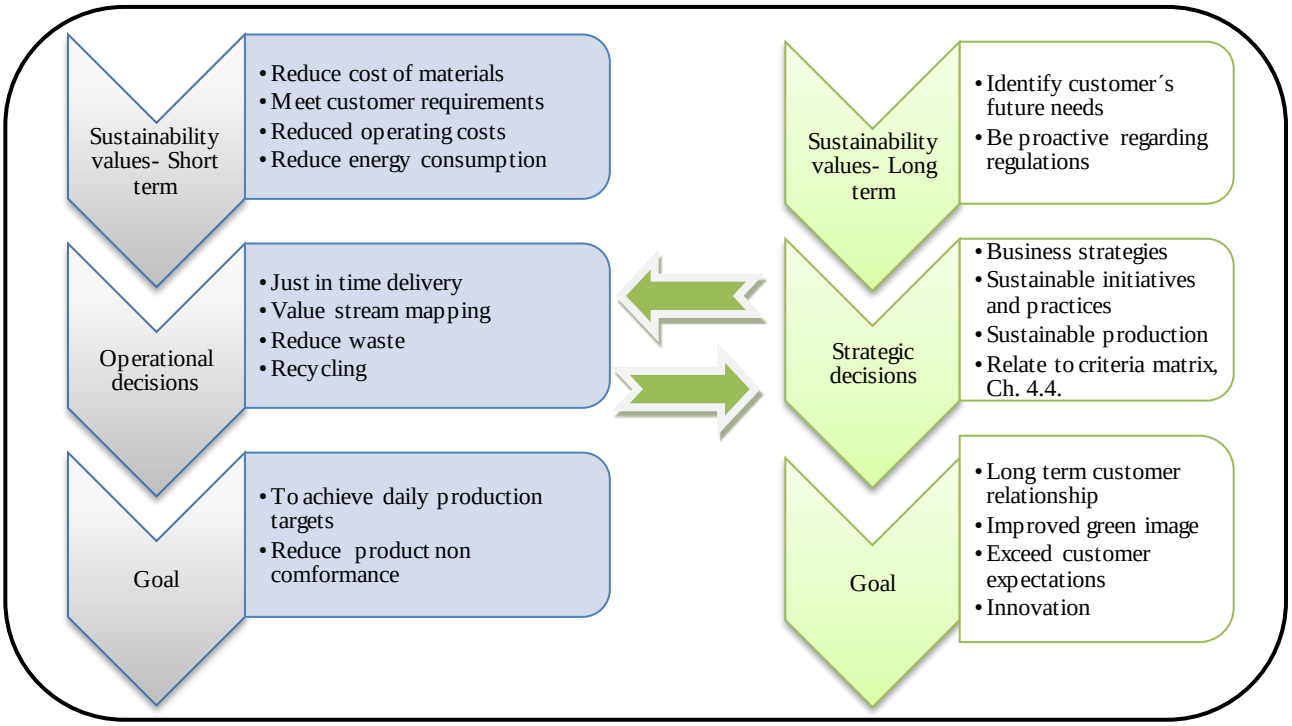

Figure 7.7: Correlation between strategic and operational decisions

Development of Vision, Mission and values statement:

Studying the annual report and websites of GKN Aerospace, there is no evidence of clear vision and mission statements relating to all dimensions of sustainability. GKN plc has values and policies depicting the commitment and promises to environmental, economic and social sustainability. But the results of interviews, bench marking and concept maps do not show evidence of these values and policies being implemented in practice. It is required to take these promises/values and align the sustainability strategy.

GKN Aerospace should develop on its own vision and mission statements and communicate internally and externally which would create a sense of responsibility among stakeholders. Mirvis, et al. (2010) indicate that "vision provides an intellectual framework for company strategy: it defines a strategic direction and presents a conceptual map of how a company moves from its current reality to a desired future state. A vision is also a motivational driver".

Senge (1990) explains the idea of vision, mission and values as follows:

- ✓ *"Vision is the 'What:' the picture of the future we seek to create.*
- ✓ *Mission is the 'Why:' the organization's answer to why we exist (purpose).*
- ✓ *Values are the 'How:' how we act to achieve our vision."*

Since GKN has the values, it could be modified to the GKN Aerospace requirements and vision mission statements could be developed. For effective statements, it should be in correspondence to the strategy of the organization. For example, Mirvis, et al. (2010) studied GKN's customer GE's ECOMAGINATION vision and conclude that their strategy and mission, vision and practices were in alignment.

Suggestions

GKN's vision statement could specify about zero emissions, zero waste, employee empowerment, leading market, increased shareholders etc.

GKN's mission statement could be designed as:

> "To design and manufacture ***Light weight products, using minimized energy and resources, having minimized waste, delivering high value to customers*** leading to economic, environmental and social sustainability"

Strategy and business impact

In this thesis, sustainability has been assessed in GKN and the current level of sustainability performance has been graded to support a plan for reaching the next step with respect to environmental and social performance. Nevertheless, the link between sustainability and business impact is missing. To clarify, the following points have been highlighted:

- Conserve resources (Environmental)
- Comply with regulations (Institutional)
- Create a good working environment (Social)
- Reduce cost (Economic)

The way competitiveness is measured on market is in mandatory terms and hence the impact of sustainability should be explored based on economy aspects. It was concluded from the interviews that it is hard to connect environmental practises to economic and business values. In addition the authors of this thesis present factors that influence the business impact, that were understood from benchmarking studies.

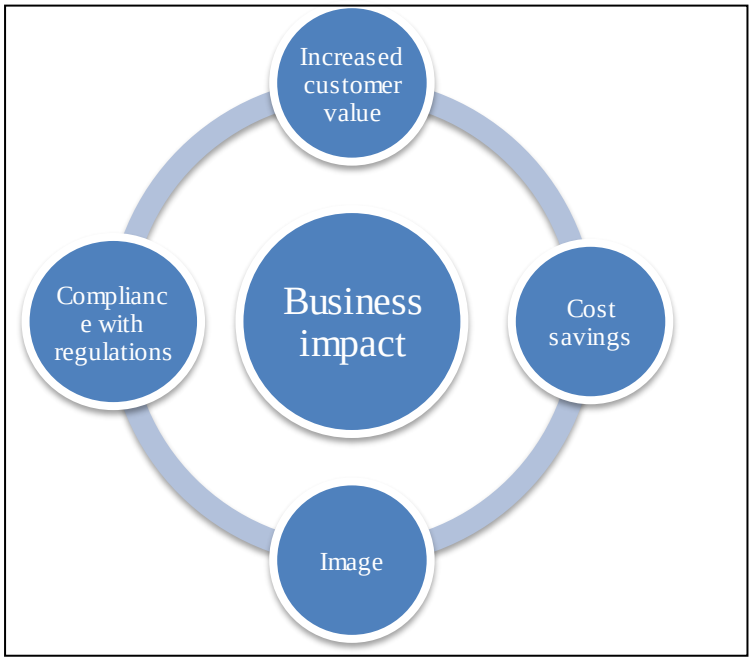

Figure 7.8: Factors that influence business of the company through sustainability

Figure 7.8 presents factors that influence business impact. To sum up, strategy should be clearly defined and communicated through whole organisation in order to bring all members on board in the process of sustainable development.

7.1.4 Set up Strategic Goals and Break down the Goals into different operation levels in GKN

Next step after strategy definition is to define the sustainability goals for the organisation. From the benchmarking results, it is observed that GKN lacks clearly defined sustainability goals. Based on defined strategy, goals should be developed covering all the three dimensions of sustainability. Environmental goals can give stakeholders a common view of where an enterprise is going that can help to align and coordinate efforts, making successful outcomes more likely (Scatsky, 2013). In relation to strategy, benchmarking studies of GE presented *Ecomagination* and *healthymagination* as initiatives to set up goals according to the three pillars of sustainability. SKF and GE have focused sustainability goals and commitments and they constantly monitor and measure their performance. They continuously develop new methods and products that foster sustainability and involve in institutional programs that helps to set guidelines and principles for practicing sustainability and focus for future.

Furthermore, Scatsky (2013) means that environmental goals are becoming an arena of corporate competition and public declarations of goals can be a way of staking out a position of leadership. This point could be adapted to other dimensions of sustainability as well. Moreover benchmarking concluded that GKN are behind competitors in their external communication of goals and strategies, whereby it is suggested that GKN set goals that improve their sustainability approach and to identify related technology and solutions.

Also, some companies consult with external institutions and local regulations like NGOs, industry bodies or government agencies for guidelines on appropriate environmental impact reduction targets.

It is essential that goal is clearly defined and Scatsky (2013) explains that sustainability goal should have two important characteristics,

1) Quantitative
2) Timeline

For example, "To reduce production wasted by *yy%* by year *2015* compared to year *2010."*

Operational level Goals

The criteria matrix served as an understanding of sustainability goals on an overall level. However to create strategic indicators on operational level these criteria matrix has to be broken down to a more understandable level. Hence LPT case example was an attempt to look into operational level, for e.g. production and product level. Zhu and Sarkis (2004) argue that "Without proper consideration of inter-relationships and coherent integration between different operations activities, sustainability objectives cannot be achieved".

For example, if the higher level goal is reducing operating costs, the corresponding operational level goals could be the following:

- Factory Lead time reduced by x%
- Inventory reduced by z%
- Improve Delivery schedule adherence to w% (Delivery Precision)
- Improving Productivity (no. of products produced per hour)
- Improving OEE by y%
- Increase Process Reliability
- Reduce cost of Transportation (Internal)
- Increasing utilization of man labour
- Reduce Scrap rate
- Increasing Energy Efficiency
- Increase Volume Flexibility
- Increase Product Flexibility
- Reduce Cost of maintenance per unit produced
- Reduce Number of breakdowns/disturbances
- Reduce cost of cutting fluids
- Reduce cost of cutting tools
- Reduce Number of Rework etc.

This does not include all, but these kinds of breakdown of higher level goals are important to understand and implement operational level activities.

7.1.5 Develop indicators for measuring the targets and Set up measurement system to monitor the progress towards the Goals

The importance of indicators and framework of sustainability measurement tool is described in the chapter 6. This could be used to track the progress of targets and achieve this step.

7.1.6 Align the initiatives to attain the Goals

This step is to make sure that the initiatives are aligned to the goals and in accordance with established strategy. These initiatives could also serve as a motivational driver for sustainable development. Tools like LCA, ecological foot printing, green engineering, natural step framework, product stewardship (EPA based tools) are generally used for environmental sustainability (Arenaa, et al., 2009).

As mentioned before in section 4.1.1, from the interviews, a list of initiatives was identified as follows:

1) Lean steering committee in production of LPT case
2) Continuous energy reduction effort from Facility department
3) Working on Imparting sustainability aspects in conceptual stage of PDP
4) Criteria and supporting tools with support from BTH
5) Environmental impact assessment (EIA) was conducted for few products and improvements
6) GRANTA database to be implemented
7) Identifying suppliers for reduced Tool cost
8) Improved cleaning methods to ensure good quality
9) Extended value stream mapping
10) Efficient packaging in containers

11) Recycling of all production wastes and using recycled materials in forging
12) All chemical wastes are cleaned before releasing to environment
13) Almost 90% recycled water for production

These initiatives should be aligned with defined goals and progress of the initiatives should be measured using the measurement system developed. These initiatives should also be linked to overall strategy to improve understanding about the company´s sustainability efforts among all stakeholders.

7.1.7 Monitor progress and communicate the results internally and externally

In common, the benchmarked companies integrate sustainability in their core business, including their environmental practices as advertisement for sustainable development. The studied companies communicate their environmental practices both externally and internally. Companies set sustainability goals not only to drive change but also to communicate with stakeholders inside and outside the company (Scatsky, 2013).

It is important to monitor progress together with customers and stakeholders to exchange knowledge about the following topics:

- ✓ Innovative Products and Applications
- ✓ Renewable Energy
- ✓ Energy Use and Efficiency
- ✓ Water Conservation
- ✓ Waste Reduction
- ✓ Transportation and Packaging

7.1.8 Review indicators, strategy and goals

It is essential to make sure that indicators support the company in reaching the goals and are accordance to the company´s goals and strategy. Continuous change in markets, regulations and environment situations can lead to change in strategy and goals of organisation and hence the higher management should review and organise the strategy, goals and associated indicators according to changes.

7.1.9 Develop a culture of sustainability practices among all stakeholders

Sustainability as a culture in the organization is essential for effective management of sustainable processes and goals. Effective communication, Reporting, organization renewal, involvement of employees and customers, etc., can help in developing and retaining the culture of sustainable development. Every member of the organization should be aligned to the sustainable thinking process.

Communication of sustainable policies, objectives and practices internally could make the higher level management and employees committed and responsible. External communication about sustainable efforts and future objectives create interests in shareholders, customers and serve as encouragement to involve in the organisation’s initiatives. This will help in gaining good will among stakeholders. Reporting the sustainability targets and achievements also profiles the company as proactive and again help in obtaining the support of shareholders and customers. Applying for sustainability awards and recognitions is a way of communicating and reporting and helps in setting targets and encouragement for improving the sustainability efforts. Organization renewal involves

forming sustainability groups with a sustainability champion and representatives from various departments having interdisciplinary actions and steps can also foster the culture of sustainable development. Enforcing the sustainability requirements in suppliers can help to improve the support and also to develop the whole supply chain of a product.

Hence, the guidelines explained will serve as an important trigger to understand the value of sustainable development in all three dimensions for GKN. Table 2.3 clarifies the maturity levels of sustainability implementation regarding strategy and financial aspects where the green zones indicate that sustainability thinking is integrated and supported in the organization, and presented guidelines will help GKN reach supportive level.

8 Conclusions

From this thesis work, the thesis authors understand that GKN has potential for sustainable development. The initiatives till now are worth contributing to sustainability. It is only important for GKN to realise the existing potential and align it to the sustainability strategy of the organisation.

The thesis work provides an understanding about the current level of sustainability performances and benchmarking, clarifying the position of GKN with other companies. To trigger the sustainable development in an effective way, it is important to implement the guidelines stepwise.

8.1 Research Questions:

Answering the research question 1, Current gaps in GKN include the following,

1) Low awareness about sustainability dimensions and their inter relation.
2) No sustainability strategy or policies in GKN.
3) Knowledge transfer is not efficient among various levels in the organisation.
4) Lack of communication about sustainability values and efforts.(Internally and Externally)
5) Pace of understanding about environmental issues and associated actions are very slow. (For e.g. risk and conflict materials)
6) Short term focus.

Answering the research question 2, the possible and successful steps for sustainable development in GKN are the developed 9 step guidelines.

8.2 Major Conclusions

On a whole, following are the major conclusions of this thesis work:

1) Understand and visualize the long term values of sustainability.
2) Focus program on sustainable development and a sustainability champion.
3) Create future goals and strategy for sustainable development integrating three pillars of sustainability.
4) Improve the sustainability reporting to gain competitiveness and image in market.
5) Create a tracking system for evaluating the objectives.
6) Involve all the Stakeholders for sustainable development and communicate the values of sustainability and initiatives internally among employees and externally to suppliers, customers and society.
7) Develop technology to reduce environmental impacts.

8.3 Future studies

Sustainable development is important in many aspects that have been covered in this thesis work. But still the connection between sustainability and business impact is vague. In this thesis work, strategy is discussed in order to identify different sustainability approaches. However for future research, the interrelation between sustainability, strategy and business impact needs to be investigated in order to ensure that sustainability efforts creates value for the stakeholders which is presented in Figure 8.1.

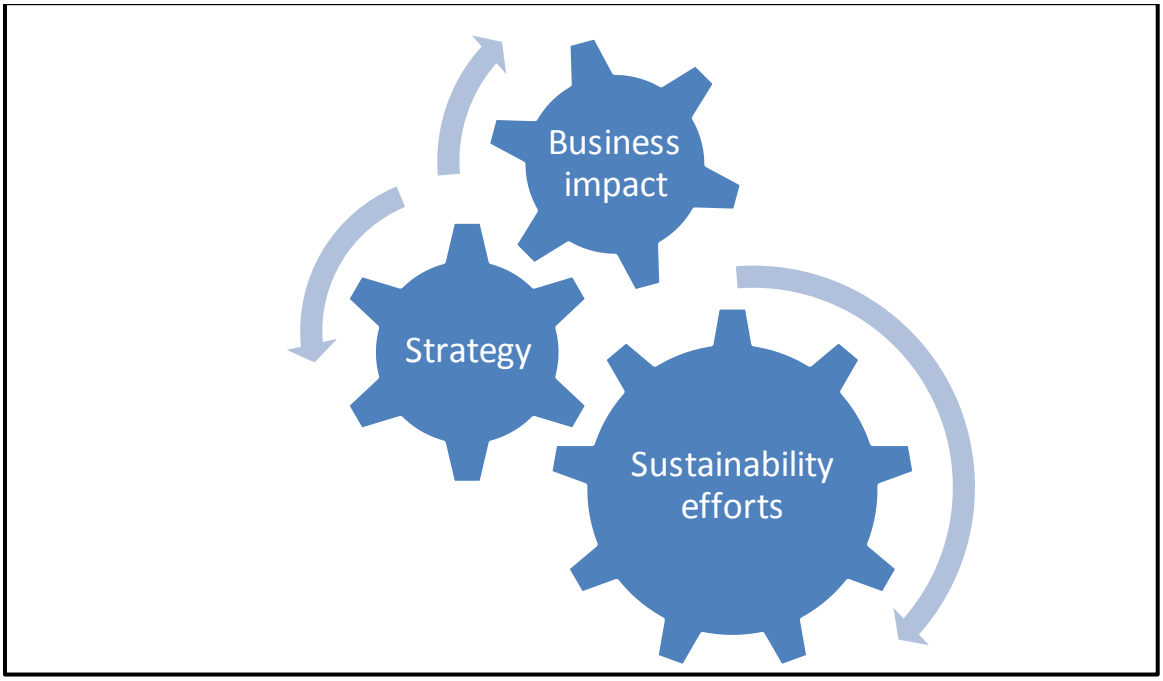

Figure 8.1: Interrelation between sustainability efforts, business impact and strategy

It is important to start focusing on sustainability and their values, but it is efficient to study the impact on the company position in value chain and decide the level of efforts to be taken. In other words, to maximize the sustainability efforts, the interaction between strategy and business impact needs to respond coherently to each other in order to ease management of sustainability over time. The size of the gears indicates the intensity for which strategy is carried out to drive a relative low sustainability efforts rate and at the same time strategy should be aligned with the market situation.

This thesis work could contribute to various future research topics that help for GKN's sustainable development and they are as follows;

- Study of sustainable development and its' business impact in GKN.
- Market study of LPT case by defining sustainability values, in alignment with customers and suppliers.
- Based on above mentioned study, identify and develop new technologies for LPT case product and production.

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Appendix A: Benchmarking Report

The companies were analysed on the following topics;

- Sustainability strategy;
- Sustainability practices;
- Sustainability indicators;
- Future goals and Commitments;
- Association with External institution programs and Recognitions;
- Focus group on sustainability and special initiatives.

SKF

Below details were obtained from SKF Annual report 2012 (SKF, 2013).

Sustainability strategy

Realizing a positive impact on the environment by:

• Reducing the negative environmental impact from SKF's operations

• Providing customers innovative technologies, products, and services that reduce customers environmental impact

Sustainability Practices

Environment care for SKF is to continually strive to reduce the negative impact to the environment from all four aspects of supply chain namely,

- Suppliers
- SKF's manufacturing operations
- Transports
- Customer solutions.

They perform the same by following the below mentioned sustainability practices.

Focus on energy reduction

- ISO 50001 implementation by 2014
- Practicing sound energy management
- Driving behavioural change
- Investment in new technologies
- New production methods

Facilities

- Sustainable building design and Construction through LEED certification and Sustainability Factory rating
- SKF's global ISO 14001 management system
- Waste water handling

- Closed-loop water consumption or installed waste water treatment facilities
- Improved separation of water, oil and metal particles.
- Regeneration and reuse in different ways
- Substitution of solvents
- REACH Regulations

Product

- Near-net-shape solutions across the full range of SKF's products
- Packaging material

Social

- OHSAS 18001 regulation in factory
- Preventable methods for zero accidents
- Community care activities around facility

Special system and methods

- Virtual warehouse system to shorten lead times, reduce transport costs and carbon dioxide emissions.
- Biogas truck which reduces the CO2 emissions related to this task by 70%

Sustainability indicators

SKF follows Global Reporting initiative guidelines to report their sustainability performance. Only environmental and social parameters are discussed below;

Environmental:

- Energy and related CO2
- Material use
- Chemicals Volatile organic compounds (VOC)
- Ozone depleting substances
- Water use
- Residual wastes and Recycling

Social:

- Accident rate for the Group
- Attendance rate
- Employee retention rate

Future goals and Commitments

1. **Raw material and components**
   100% of SKF's energy-intensive major suppliers certified according to ISO 50001 Energy management Standard by 2016.

2. **SKF's own operations (Scope 1 and 2)**
   Reduce the total annual energy use of the SKF Group by 5% below 2006's level by 2016. Reduce the energy use per production output by 5% year-on-year.
3. **Products and solutions**
   Increase the revenue from the SKF *BeyondZero* portfolio from SEK 2.5 billion in 2011 to SEK 10 billion by 2016.
4. **Transport and distribution**
   Reduce CO2 emissions per tonne-kilometre for all transport managed by SKF Logistics Services by 30% below 2011's level, by the end of 2016.

Association with External institution programs and Recognitions

SKF works together with the following institutions to improve on a continuous basis and rate their sustainability performance:

1. GRI reporting initiative (G3).
2. Dow jones sustainability index(2012-13)
3. IEQ Industrial Engineering
4. FTSE4Good Index Series(2001)
5. Ethibel Pioneer and Ethibel Excellence Investment Registers (2005)
6. ILO Declaration Concerning multinational companies
7. ICC Charter For sustainable development
8. United Nations Global Compact
9. OECD Guidelines for multinationals

Focus group on sustainability and special initiatives

As mentioned in the introduction SKF has a focus groups called beyond zero (SKF, 2013), which is an introduced concept in the company towards sustainable development. This initiative has two overall objectives;

- Reduce the negative environmental impact from our own operations and those of our suppliers.
- Innovate, offering our customers new technologies, products and services with enhanced environmental performance characteristics.

GE

Below details were obtained from GE Annual report 2012 (GE, 2013).

Sustainability strategy

"Both Ecomagination and Healthymagination tie the sustainability message to the company's portfolio, highlighting the fact that GE is both a responsible organization in its own right and that it also helps customers around the world become sustainable" (GE, 2013).

Sustainability Practices

Environment

- Water Kaizen events for an especially effective strategy for analysing and reducing water use at our facilities.
- Energy efficient products
- Energy Treasure Hunt process
- Leadership in Energy and Environmental Design (LEED)–certified facilities
- Life cycle management
- Renewable energy
- Bio diversity
- Optimizing material use
- Recycling
- Reclaim and reuse

Social

- Environmental health and safety, training and development for Employees
- Local community care and development

Special systems and Methods

- Supplier management systems tool and supplier partnership program
- Measuring business' and sites' performance against the Eco Framework
- Internal monitoring and tracking system

Sustainability indicators

Environment

- Air and waste water
- Toxic Release inventory On-Site Releases (in millions of pounds)
- Water use
- Waste generation Hazardous
- Waste generation Non hazardous
- Recycled metals
- GE Operational GHG Emissions
- GE Operational GHG Intensity
- GE Operational Energy Intensity
- GE Operational Energy
- Use Spills & Releases

Social

- Training Units Completed
- Agency Inspections U.S.
- Agency Inspections Non-U.S.
- Supplier performance
- Health & Safety
- Environment
- Emergency Preparedness

- Labour
- Dormitory

Economy

- Ecomagination R&D Investment (in $ billions)
- Ecomagination Revenue (in $ billions)
- Global Penalties Paid

Future Goals and Commitments

Environmental

- Reduce absolute GHG emissions by 25% by 2015 (against 2004 baseline).
- Improve energy intensity of GE operations by 50% by 2015.
- Reduce freshwater use by 25% by 2015 (against 2006 baseline).
- Reduce wastewater and air exceedances, and reportable spills.

Social

- Complete 100% of required initial and refresher EHS training for all employees.
- Develop or revamp specialized training for Services and Fixed
- Facilities leaders to strengthen early-hazard recognition and risk management skills, and an EHS course for supervisors and shop floor leaders.
- Roll out product stewardship training.

Economy

- Starting in 2010, double to $10 billion our R&D investment in Ecomagination over the next five years versus the previous five years.
- Commit to growing Ecomagination product revenues at twice the rate of GE's overall revenue between now and 2015.

Association with External institution programs and Recognitions

- GRI G3 reporting initiative
- UN global Compact
- In 2011 GE won the prestigious Carbon Saver Gold Standard award as part of the UK's Carbon Reduction Commitment (CRC) program

Focus group on sustainability

Equally as SKF´s concept "Beyond zero, GE has "Ecomagination" (GE, 2013) as a concept to show their responsibility towards sustainable development as an original equipment manufacturer.

"Ecomagination stands as our commitment that Proficy can offer unique value to you in these interrelated areas" (GE, 2013):

- ✓ Improve overall process efficiency by approximately 3%-15%
- ✓ Reduce waste and defects in manufacturing and infrastructure applications by approximately 1%-10%
- ✓ Reduce the average energy usage associated with operations

MTU

Below details were obtained from MTU Annual report 2012 (MTU Aero Engines, 2013).

MTU has similar production as GKN and is thereby one of GKN´s competitor (having Pratt and Whitney and general Electric as customers) in the market of low pressure turbine cases and other components within the aviation industry.

The MTU principles are based on six pillars:

- Technology and Growth
- Cooperation and Conduct
- Staff and Management
- Partners, Customers and Shareholders
- Environment and Society
- Materiality matrix: identifying important sustainability topics

Sustainability strategy

Innovation is one of MTU's strategic pillars and eco-efficiency is a primary focus when we develop new products and technologies. Also expansion of sustainability report to include further GRI indicators.

- Partnerships with big global engine manufacturers
- Investment in future technologies in
- conjunction with long-term emissions and
- noise reduction targets
- Participation in attractive forward-looking
- engine programs
- Balanced product portfolio
- Stable and long-term customer relationships
- Motivated and healthy employees
- Solid positioning in global growth markets

Sustainability Practices

- Monitoring and recertification audits to be passed in accordance with OHSAS 18001 in MTU Group insofar as locations are already certified.
- Employee training courses on sustainable resource consumption and the company's environmental activities

Products

The Geared Turbofan is due to enter regular service with commercial airlines from 2015 onwards. It is impressively eco-efficient, with 15 percent less CO2 emissions and half the subjectively perceived noise level of traditional engines.

Special systems and Methods

Introduction of series-produced components made straight from a powder bed following CAD data using new laser-based additive manufacturing techniques. This significantly reduces the amount of material used.

Water recycling

Best practice: Electroplating water circuit (water recirculation) an ion exchange plant is used to create a rinse water circuit that enables large volumes to be reused. In 2012 full volume, 257 cubic meters, was circulated and reused 6.5 times a day.

Focus areas where goals are stated and related to environmental management in manufacturing are:

- *Reducing consumption of energy and resources*
- *Material efficiency*
- *Sustainable construction*
- *Environmental certifications*

Sustainability indicators

GRI (Global reporting initiative) Index are used and here are some examples:

Environmental

- Energy consumption (KWh)
- Water consumption (m^3)
- Material consumption (tons)
- Direct and indirect greenhouse gas emissions
- NOx, SOx and other significant emissions (tons)
- Significant fines and sanctions for non-compliance with environmental laws

Social

- Percentage of security personnel trained on aspects of human rights that are relevant to operations
- Increase in percentage of women to 15%

Future Goals and Commitments

Environmental

Below several goals are presented, from year 2000 or earlier according to ACARE is to:

- Aircraft engines to emit 30 percent less CO2 until 2035
- Reduce fuel consumption and CO2 emissions by 50 % per passenger kilometres until 2035
- Reduce emissions by 80 % until 2035
- Reduce perceived noise by 50 % until 2035
- 15 % reduction CO2 emissions through first gear turbofan generation until year 2015
- 20 % reduction in CO2 emissions through second geared turbofan generation until year 2025

- 30 % reduction in CO2 emissions through third geared turbofan generation 2025
- 20 dB reduction in noise emissions through geared turbofan generation 2020
- Supporting the introduction of sustainable fuels with MTU expertise via participation in research programs.
- Cooling with well water, for instance, saves around 3,000 tons of CO2 annually, while using the cogeneration plant can cut CO2 emissions by as much as 7,400 tons per year.
- The long-term aim is to cut CO2 emissions from product manufacturing and maintenance activities at our main plant in Munich by up to 25 percent by the year 2020 (compared to figures from the year 1990).

Association with External institution programs and Recognitions

In 2012, MTU was again awarded the Supplier Gold Award from Pratt & Whitney's parent company United Technologies Corporation (UTC) in recognition of the out- standing quality of its products, its on-time deliveries and a high level of customer satisfaction. The *MTU CLAIR-IS program*- a technology roadmap towards more eco efficient products. Within the time period 2000 to 2035 different goals are set and some of these goals are:

- Reduced CO2 emissions through Clean Air Engine technology program.
- Reduce CO2 emissions at their headquarters in Munich (representing the majority of their production) by 25 percent by the year 2020.
- GRI (Global reporting index).

GKN

Below details were obtained from GKN Annual report 2012 (GKN PLC, 2013).

Sustainability strategy

GKN aerospace strategy includes sustainability that says, "*Our goal is to have a positive impact on the environment and communities in which we operate. We aim to operate in a sustainable, ethical, efficient and safe manner".* This means that GKN aerospace is thinking about sustainability aspects and implementing processes for the same.

Respective improvements include the following,

- Creating Operational Excellence through Lean manufacturing and innovative engineering.
- Creating a long term sustainable value through 12 Promises.
- Development of light weight, Fuel efficient products reducing carbon emissions.
- Development of alternative materials.
- ISO140001.
- Safety programs and reduced accidents

At the same time, it is hard to see any future goals or commitments relating sustainability. Unlike other companies, there is no sustainability programs/focus groups established until now. Also, it was seen that, safety issues were taken into high consideration and improvement are continuously recorded through safety training and programs.

Sustainable practices

- Developed system for recycling of water
- Lean production
    - Value stream mapping
    - Tool cost reduction
    - 5 S

Sustainability indicators

Environment

- Energy consumption per unit of production
- CO2 emissions per unit of production
- Waste generation per unit of production
- Water consumption per unit of production
- Recycled waste

Social

- Accident Frequency rate
- Number of lost time accidents per 1000 employees
- Accident severity rate
- Number of days/shifts lost due to accidents and occupational ill health per 1000 employees

Future Goals and Commitments

- Safe working environment
- Reduced use of resources
- Environmental impact
- Sustainably sourced raw materials
- To improve Energy efficiency by 15%

Association with External institution programs and Recognitions

Not communicated.

Focus groups on sustainability

In GKN sustainability groups including researchers, managers and engineers are being formed to discuss sustainability in GKN. This group is a result of one initiative to highlight sustainability issues in the company.