Environment-oriented Logistics System Design

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Abstract

Environmental issues have been highly in focus for several years. With the development of EMS, many companies get environmental improvements through implementing EMS. Also, “green logistics” turns out to be a popular issue. But the combination of environment issues and logistics system is rarely found in the previous researches. Therefore, environment-oriented logistics system design becomes the topic described here.

The purpose of the thesis is to see potential of integrating environment issues into logistic system by literature review and case study. With the help of our supervisors, two Swedish companies Sandvik SMT and FLB Logistik become case companies in the thesis. The analysis is based on literature review about logistics and environment, the information from both companies’ websites as well as face-to-face interviews.

In analysis part, how logistics systems and environmental issues interact with each other is illustrated firstly. A proposed model based on logistics system decision-making model is shown. SWOT analysis is used to explain the outcomes and challenges of implementing EMS in Sandvik SMT. At last, the conditions such as customer environmental requirement and the cost for using EMS are briefly described.

Based on the research, further study should begin with the collection of quantitative data about environmental performance from manufacturing companies, suppliers, as well as retailers. More recommendations are given in the conclusion part.
# Content

1. Introduction .................................................................................................................. 1
   1.1. Background .............................................................................................................. 1
   1.2. Problem Discussion ............................................................................................... 4
   1.3. Purpose ..................................................................................................................... 5
   1.4. Overview of the Case Companies .......................................................................... 6
   1.5. Disposition .............................................................................................................. 7
2. Methodology .................................................................................................................. 7
   2.1. Data collection and analysis .................................................................................... 7
   2.2. The analytical process ............................................................................................ 10
   2.3. Limitation .............................................................................................................. 10
3. Theoretical Framework ................................................................................................. 11
   3.1. Logistics effect on environmental performance ..................................................... 11
   3.2. Environmental impact on designing logistics systems ........................................... 15
   3.3. Environmental Management System (EMS) .......................................................... 17
   3.4. ISO 14001 .............................................................................................................. 18
   3.5. Combination of EMS and logistics systems ............................................................ 20
   3.6. SWOT Analysis ..................................................................................................... 21
4. Description .................................................................................................................... 21
   4.1. Case description of Sandvik .................................................................................. 21
   4.2. Case Description of FLB ......................................................................................... 26
   4.3. The comparison between Sandvik SMT and FLB .................................................. 27
5. Analysis ........................................................................................................................ 28
   5.1. Logistics effect on environmental performance ..................................................... 28
   5.2. The environmental impact on designing logistics system ...................................... 32
   5.3. Outcomes and Challenges of implementing EMS in logistics system .................. 36
   5.4. The conditions for using EMS .............................................................................. 40
6. Discussion ...................................................................................................................... 41
   6.1. Conflicts between theory and findings .................................................................... 41
   6.2. Change management in practice .......................................................................... 42
   6.3 Problems in outsourcing ......................................................................................... 42
7. Conclusions and Recommendations ............................................................................. 42
8. Future Study ................................................................................................................... 43
References ......................................................................................................................... 44
Appendix 1 ......................................................................................................................... 48
Appendix 2 ......................................................................................................................... 50
Appendix 3 ......................................................................................................................... 51
1. Introduction

1.1. Background

1.1.1. Milestones on the green pathway

Today, there are many aspects of human life on earth that are moving in a positive direction. Life levels in most countries have improved significantly in the last 30 years. In 1995, Peattie K. studied the green challenge, mentioned “Although the last 30 years has contained a number of disturbing revelations about the environment, many steps have been taken to protect and improve its quality” and showed the milestones which maps out some of the disasters and the responses that have driven the environmental debate forward since the early 1960s.

Data collected by Environmental Assessment Group from Eco Community Programme IMRIC U of Greenwich. Rachel Carsson’s Silent spring Global Problems with Insecticides was published in 1962, the first earth day and US national environmental protection act had been fixed in 1972. Till the early 1980s the environmental audit have carried out by many large companies, European commission agreed first environmental assessment regulation in 1985. The following events, such as publication of Brundtland Report, entrenching sustainable development as key strategic dimension in environmental policy (1987), implementation across Europe of Environmental Assessment Directive (1988), proposal for European environmental Agency (1991), draft Eco-Audit Directive, Europe (1991) and GATT publishes report on world free trade and environmental issues(1992) etc. (Peattie K. 1995) And the United Nations Conference on Environment and Development (UNCED) was held from June 3 through June 14, 1992, in Rio de Janeiro, Brazil. It was held twenty years after the UNCHE took place in Stockholm, Sweden. Five major agreements on global environmental issues were signed in this conference. (UN, 2009)

In 1996, at the request of UNCED, the International Organization for Standardization (ISO) introduced ISO 14001, the first of the ISO 14000 family of environmental management systems (EMS) standards. Many prior researches have evaluated the reasons why the organizations want to adopt an EMS. In Bansal and Hunter’s study, the goals of ISO 14001 were twofold. At a corporate level, ISO 14001 was designed to help the organizations reduce their environmental impact while improving management control. At a social level, ISO 14001 was intended to facilitate sustainable development and foster international trade by providing an internationally
legitimized system of standardization. (Bansal and Hunter, 2003) Nowadays, the concept of sustainable development has become widespread in government agencies, politicians, corporations and other organizations throughout the world. And since the World Business Council for Sustainable Development (WBCSD) embarked on developing a clear understanding of CSR in 1999, CSR has been a subject intense debate by the researchers. The firms’ performance to the society received much attention. This responsibility includes the impact of their activities on the environment, consumers, employees, stakeholders and all other members of the public sphere. (Galbreath J. 2008) Although social issues are just important as environmental issues in the business, social issues seems to be much visible, environmental issues are easily being neglected and they will be the major focus of this study.

1.1.2. Driving forces of environment-oriented logistics systems

The early research shows that transportation became one of the most important factors of environmental influences. When the other economic sectors have significantly decreased their emission over the last decade, the transport sector accounted for 32 percent of the total energy consumption in the EU in 2001. (Eurostat, 2003) The emission rate is growing faster and faster. The worrying fact is that this rate is even faster than the growth of GNP in industry in the last 15 years from the statistic of European Commission. It makes EU being deeply concerned about this situation and trying to find out a better way to decrease the influence to the environment. (European Commission, 2001) Reducing the environment impact of transport as one of the objectives adopted in the official paper *European transport policy for 2010* which published in 2001. And the transportation is the biggest part in logistics system, under the social responsibility pressure, the companies started to integrating the environmental issues with their logistics system design.

Large number of organizations are running whether certified EMS or uncertified EMS today. The possibility of using environmental management systems as a tool for the logistic management became an interesting research problem. Why the organizations want to adopt EMS had been described before, turn the discussion back to their business. The market competition was always described as hard, when the customers much concerned the environment issues today, environmental requirements were taken seriously as a precondition for organizations. (Nawrocka D. 2007) The EMS adopters have to “Green” their business since they marketed themselves as environmental proactive companies.

On the other hand, questions remain about whether companies are using their EMSs to challenge their supplier networks to become more environmental sustainable. (Darnall and Jolley, 2008) Under the pressure of fierce competition, for the purpose of reducing the cost and optimizing the resource, the companies need outsourcing to help
them cut some weakness and concentrate in their core business. That means the companies have to build a relationship with their suppliers, because supplier is a part of companies’ business now which has the influence on their business performance. Because of the environmental requirement, the companies have to take action to control the environmental performance in their supply chain.

1.1.3. The adoption of EMS (ISO14001)

By April 2005, more than 88800 facilities in 127 countries had got the certification of ISO 14001 for their environmental management systems (Peglau R. 2005; ISO 2004b), and many other organizations had adopted the uncertified environmental management system. Environmental Management System is strategic management approach which helps the organizations reduce environmental risks by standardizing practices and promoting continuous improvement. Although it is a trend forces the organizations to certify their environmental performance, to get a certification is not an easy job for all organizations. For example, financial problem have been considered as one of the difficulties for SMEs implementing EMSs. (Perez-Sanchez and Barton, 2003) Facing the own resource constraints including the aspects of funding, technology, management system, internal and external resources etc., some kind of companies are forced to save cost in environmental performance but choose to have the initiative in professional knowledge and skills. Because of lack of technology and resource, the research and development of implementing EMS can not at a high level. Because ISO 14001 within an independent third party auditor, who helps to ensure that the EMS conforms to the ISO 14001 standard. So that in the preparation for certification, the organizations have to spend a lot of money, time and energy in meeting the standard and forming their EMS with a series of procedures and plans.

However, once the organizations got the certification, the ISO 14001 label indicates that the organizations have adopted an environmental management system which documents the organization’s pollution aspects and impacts, and indentifies a pollution prevention process for them, and it is continually improved over time. (Darnall N. 2006) Because of this, many organizations think that ISO 14001 is not only help them to optimize their resource but also enhance their corporate image and increase profits (Stapleton and Glover, 2001) From sustainable development’s point of view, EMS may increase organizations’ economic gains by improving environmental performance, operational efficiencies, customer satisfaction and new access to markets.

1.1.4. Future strategy for logistics development

*Lean thinking in business*

Environment-oriented is trend for the social development, most of the organizations
would like to go after the sustainable development for their business. There are two main aspects highly focused by the organizations today, low costs and environmental performance. Cost efficiency and environmental responsibility seems mutually exclusive, but actually not. Some social institutions started doing research in this subject in the latest years. In Nov. 17, 2009, a two-day lean and green supply chain strategic summit conference were held in Canada. The agenda of conference includes the speech Understanding the True Value of Being Green: Reducing Cost and Improving Environmental Performance from Hewlett Packard Company’s Ed Costa, program manager of Global social and Environmental Responsibility Operations, Measuring The Effectiveness and Overall Success of Your Green Supply Chain Initiative: Benchmarks and Performance Indicators from Stephen Stokes, AMR Research (Boston), Performing Supplier Evaluation, Certification and Outreach to Ensure Your Supply Chain is Actually ‘Green’ from Carol Boutin, the program manager of Sustainability Purchasing Network, and the speech from Jack Ampuja, the president of Supply Chain Optimizers (New York), Developing ‘Optimal Logistics Networks’: Benefit the Environment and Your Bottom Line etc. (Strategic Institute, 2009) This kind of conferences is much concerned by people now. Learning from the case of others, no matter success or fail, to save time and money and reduce risk is a wise move for us.

The scope of lean thinking
A critical point in the lean thinking is the focus on value. Value creation seemingly equal to cost reduction. This represents a common yet critical shortcoming of the understanding of lean. Actually, the core idea of lean is to maximize customer value while minimizing waste. (Lean Enterprise Institute, 2009) That means it is possible to create more value for customers with less resources. It is a way to improve the cost efficiency and sustainable development for the enterprises. For reaching the target of providing a perfect value for the customers and zero waste, the enterprises change their focus from separately managing their component element of business to optimizing the follow of productions and services through entire value streams in their business. In a research about the review of contemporary lean thinking mentioned that any concept that provides customer value can be in line with a lean strategy. It can be involved in the aspects about production, capacity, quality, responsiveness of manufacturing system, demand variability, availability of production resources, and production control approaches and service environment etc. (Hines and Holweg, 2004).

1.2. Problem Discussion

The increasing environmental impact points out that the related institutions should increase their involvement and try to find out some proper ways to reduce the environmental problem. The air pollution and energy consumption result from the
transportation are calling attention by people to consider organization’s logistic structure. How logistics systems influence on environmental performance and how environmental impact affect on logistics systems designing have brought into consideration. With the adoption of EMS and ISO 14001 certification by many organizations, the possibility of using EMSs as a tool for the logistics management seems to be worth doing. And this is a trend for logistic development in the future. The activities which are mostly related to the environmental performance need to be pointed. At the same time, the application of EMSs and ISO 14001 are not so proficient for most of them because of the lacking restriction. The companies will face a lot of challenges in the process of implementing EMS in logistics systems.

Improving environmental performance becomes more and more important to an organization’s success. Through the thesis studies which focus on the interaction between environmental performance and logistic system, it aims to find a way which helps organizations to reach the ideal condition that getting the cost efficiency and environmental responsibility at the same time. The best choice for organizations to reach sustainable development is to effectively control the costs, as well as to reduce the waste of resources and environmental pollution. This is a twofold effect that once the organizations adopt EMS, they can examine the possibilities of enhancing their logistic system performance while reducing the negative impact on the ecosystems in the logistic operation, as well as finding out the proactive solutions in order to optimize their cost use. In the process of thesis study, there are not many scientific papers specialized in the combination of these two concept lean and environment-oriented before. Although this is not a major study of the thesis, it is still interesting to get an output of topic, to see how to implement a sustainable logistics system with cost optimization and environmental responsibility at the same time.

1.3. Purpose

The purpose of our thesis is to see potential of integrating environment issues into logistics system by literature review and case study.

The research questions are listed as follow:

- How activities which exist in logistics systems interact with environmental performance?
- What are the fundamentals of designing environment-oriented logistics system?
- Considering the role of EMS, what are the outcomes and challenges for implementing EMS in practice in logistics system?
- Whether it is possible to fulfill cost efficiency and environmental responsibility at the same time and provide some insight about the framework for undertaking EMS.
1.4. Overview of the Case Companies

1.4.1. Background of Sandvik

Sandvik is a global company which founded in Sandviken, Sweden in 1862. It is a high-technology engineering group with advanced products and a world-leading position within selected areas. Sandvik today has already stretched its worldwide business activities into 130 countries in Africa, Asia, Australia New Zealand, Europe, Latin America and North America. (Sandvik, 2009)

Sandvik consists of three business areas: Sandvik Tooling which focuses mainly on tools and tooling systems for metalworking applications; (Sandvik Tooling, 2009) Sandvik Mining and Construction (SMC) as providers of equipment and solutions for many mining and construction relevant activities; (Sandvik Mining and Construction, 2009) Sandvik Material Technology (SMT): It is a world leading producer of high technology stainless steels, special alloy materials and advanced value-added products, developed in close cooperation with customers. (Sandvik Materials Technology, 2009)

As a global company, Sandvik think that “Financial success is not enough for a leading” (Sandvik. Annual report, 2008) Sandvik has a long-term strategy for profitable growth and sustainability development by honoring their social and environmental responsibility and conducting business in an ethical way.

1.4.2. Background of FLB Logistik

FLB is a local logistics company which founded in 1989, in Gavle, Sweden. There is three main location in Gavle, total 1700 m². FLB is a growing third party logistics company focusing on the telecom and electronic industry sector which provide reliability, speed and cost effectiveness to its customers. Through the years FLB have acquired both national and international companies that operate in the same area as their customers, such as Ericsson, ASPTEC, Panasonic and NEFAB.

FLB’s services include:

*Basics services*: local and international transportation, inbound handing, storing, outbound handing, bonded warehouse and customers’ administration, stock and transaction reports

*Value add services*: production, quality support, reversed logistics

(FLB, 2009)
1.5. Disposition

This part has provided a general view of our thesis and showed research possibility to the readers. The following parts are methodology, theoretical framework, description, analysis, discussion, conclusion and limitation of our paper. In part 2, the research methods, reliability of data and the limitation of this thesis were showed. There is a summary of the theories and models related to the literatures study in part 3. The overview of the case companies and the information from the interviews were described in part 4. Part 5 presents an analytic process for the finding of the case study. After using the models and theories to analyze the empirical finding, part 6 discuss the new problems which were found out during the study. Part 7 is a conclusion of the thesis, some recommendation were given also. And which aspects in the thesis can be improved was discussed in Part 8.

2. Methodology

According to the purpose of the thesis, it is aimed to integrate EMS into logistics system by analyzing two companies. The overall research plan is in accordance with as listed below:

- Deciding the research direction
- Reading scientific papers
- Collecting ideas from related resource
- Choosing the related theories and models to build the theoretical framework
- Going to the empirical finding by interviews and cases study
- Combine with theoretical framework to analyze the data from the finding part
- Concluding the results from the analysis

The interviews are conducted in different working area people and two different companies. During this process, two important books Your Research Project (Walliman N., 2005) and An introduction to qualitative research (Flick U., 2006) acted as guides of thesis writing.

2.1. Data collection and analysis

The data were collected and systematically analyzed throughout the research by the following research methods.

2.1.1. Literature review

Since there are not many researches which combined EMS with logistics system, the
separate knowledge from different areas about EMS and logistics system are needed to be studied. Reading materials were the first choice for study. We had a wide range of background knowledge about logistics from related courses before, but we were not very familiar with every specific component in logistics system or supply chain. The purpose of this thesis is to see potential of integrating environment issues into logistic system. The possible impacts between logistics and environment are the first knowledge aspect needs to be studied. The books about logistic and supply chain management from the library and the textbook *Environmental Management* were the first reading material we chose. The books we have chosen are listed included in the references.

After collecting the ideas for writing, our supervisors Kaisu and Robin gave us some scientific papers. For instances, environmental impact of changing logistic system, the use of EMSs in supply chain management etc. Then, in order to supplement of our thesis study, we collected a lot of information from the slides of our previous courses and read many relevant literatures from Journals and database, such as Emerald, Science direct and Google Scholar to deepen our knowledge and try to create the own approaches for the analysis. These different information sources have been interpreted and summarized into our theoretical framework.

### 2.1.2. Cases study

In the empirical finding, two companies are chosen to compare their environmental issues on their business. One is a global company Sandvik, the other is a local company FLB.

Sandvik SMT is the main research area in the thesis. As a worldwide company, Sandvik SMT has a high requirement of environment as building its market role as an environment-oriented company. Sandvik SMT believes that it will succeed in fostering the value by contributing to sustainable economic, social and environmental development. 80% units of Sandvik have adopted ISO 14001 now and Sandvik SMT has a complete environmental management system to control their environmental performance. It is interesting to see how EMS implementation runs in a company and the benefits of using it.

As a third party logistic company, to deliver goods is the main business of FLB. There are many environmental factors like energy waste and emission should be considered in the process of transportation. FLB have more requirements on environmental issues today, both work environment and others. The customers of FLB are from a variety of industrial and commercial sectors whose requirement is to achieve reliability, speed and cost effectiveness. Cost effectiveness and environmental responsibility are seems to be inconsistent. How did FLB balance these two aspects and the need of environmental management system for FLB were the reasons why we chose this case
company to study.

The main resources of these two companies were collected from their websites. Sandvik.com is informative and helpful to the study. A lot of open resources like Sandvik Annual Report, Code of Conduct, and Sustainability Report even its financial key figures from the latest ten years can be downloaded. The remaining information based on the previous guest lectures, visit of FLB and interviews.

2.1.3. Interview methods

The main part of empirical finding from the thesis study is through several interviews, this process allowed further discussion beyond the interview questions, so a qualitative approach was being used in the study.

After choosing our case companies Sandvik and FLB, to get a wide perspective of the situation we tried to contact as many different divisions as possible within the related employees in these two companies. The first interviewee was a freight manager from Sandvik SMT who was recommended by our supervisors Kaisu and Robin. And then we contacted a manager from FLB who was our guest lecturer for the course strategies and principles for effective logistics before. The final person we found was a leader from Sandvik group.

<table>
<thead>
<tr>
<th>Interviewee 1</th>
<th>Company</th>
<th>Job Area</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sandvik Material Technology</td>
<td>Distruion Transportation</td>
<td>Freight manager</td>
</tr>
<tr>
<td>Interviewee 2</td>
<td>FLB logistik AB</td>
<td>Logistic management</td>
<td>Logistic service Manager</td>
</tr>
<tr>
<td>Interviewee 3</td>
<td>Sandvik Group</td>
<td>Communication</td>
<td>Vice President</td>
</tr>
</tbody>
</table>

Table 1 Interviewees’ information (source: authors adapted from interviews)

The interviews with the first two interviewees were face to face, the interview with the vice president was done by E-mail. The interview questions list was sent to Anders and he replied all of the questions. The interview questions lists were attached as Appendix 1 and Appendix 2.

The arrangement of our interview questions is following our reading order. The questions were divided into four parts, logistic system, environmental performance, the environmental impact on designing logistic system and the implementation of environment management system in logistic systems. And some cost problems were also being asked throughout the interview. Most of the questions were open and
created in a way that the interviewees can not be guided into the answer or just answer yes or no, but continue to describe and discuss. Especially, through the interview of FLB we needed to explore some solutions and wish to get information which we cannot predict, so a very open and unstructured form of interview questions was being appropriately designed.

For the preparation of each interview, a lot of background information about the companies and interviewees are searched from websites. Each interview question is tested to ask and answer by authors, in order to find best way to ask in the interview. We started the interview with asking the job description of the interviewee and telling them the purpose of our thesis. Because of the time limitation, we recorded the whole interviews process, so that we didn’t need to spend a lot of time to mark down the notes, but kept discussing and made more and more ideas come out to the mind. After every interview there was a much clear picture in our mind, we were allowed to send E-mail to our interviewees if there were something more we want to know. The content of the every interview was summarized and sent to the interviewees, the interviewees had to check the data validity before it publishes. In this way, we can have the opportunity to correct our resources and get a feedback from the companies and enhance the better communication with them.

2.2. The analytical process

The theories and models in this thesis study have been chosen by following the analysis process. In order to know the interaction between logistics system and environment, the environmental influences of logistics activities and what changes in logistics system can contribute to the environment are analyzed by the Environmental Performance Evaluation model, logistics system activities, flexibility and time-based theories first. And then the logistics system decision-making model is to help understanding more about what kinds of factors are the priorities for consideration. Introduce the application of EMS after that, SWOT analysis is used to describe the implementation of EMS in Sandvik SMT logistics system. And the outcomes and challenges of implementing EMS are analyzed following the structures of EMS and ISO 14001 model. The rest of analysis, discussion and recommendation in thesis study base on the theories about the environmental perspectives on transportation and suppliers from literature reviews and courses study such as change management before.

2.3. Limitation

Due to limited time and lack of resources, the interviews are not enough for getting quantitative data about environmental issues during the research. As Sandvik SMT is a worldwide company with completed network and organization structure. Therefore,
the focal study was on logistic part. During the ongoing research in Sandvik SMT, the resource collecting ways were limited. The main logistic activities information was got from a freight manager who is response for distribution planning in Sandvik SMT.

During the analysis, most information according to environmental management system in Sandvik SMT was collected from Sandvik’s sustainability report. It is difficult to evaluate its validity. Although Sandvik’s sustainable report is informative, the data from this report can only be secondary data. It is hard to collect accurate quantitative data about environmental indicators during the interviews. In the thesis, only the factors of environmental performance which related to logistic are analyzed and the other factors which come from the influence of production and management etc. is not included. Therefore the thesis study can only rely on the statistics from the sustainable report which showed a general data collection for the whole Sandvik’s environmental aspects.

There are not so many models and theories combined the logistic system with environmental management system which can be found from literatures. The supplier control is described in most of the literatures, but not the whole logistic system. SWOT analysis which used in the thesis also has its own limitations. Thus, there are authors that consider it a simplistic, static and subjective technique, that it does not communicate any information in itself, that its results depend on the analyst that carries it out, etc. (Panagiotou and Van Wijnen, 2005).

3. Theoretical Framework

3.1. Logistics effect on environmental performance

3.1.1. Environmental Performance Evaluation (EPE)

According to ISO 14031, Environmental Performance Evaluation (EPE) is “a process to facilitate management decisions regarding an organization’s environmental performance by selecting indicators, collecting and analyzing data, assessing information against environmental performance criteria, reporting and communicating, and periodic review and improvement of this” (International Organization for Standardization, 1999). It means that when the organizations evaluate their environmental performance, they need to select indicators as precondition. Kolk and Mauser (2002) have categorized indicators into 3 groups. All results are summarized from the ISO 14031, the GRI and the eco-efficiency guide of the World Business Council for Sustainable Development (WBCSD). Three elements are distinguished as below:

- Environmental management indicators (EMIs). These indicators provide
information about the effects of the management to influence the environmental performance of the organization’s operations.

- Environmental condition indicators (ECIs). These indicators provide information about the direct impacts of the organization’s operations to the environment.
- Environmental performance indicators (EPIs). The operational performance indicators (OPIs) provide information about the environmental performance of specific organization’s operations, while the impact performance indicators (IPSs) provide information about the outputs of the organizations’ operations (Diakaki, 2006).

![Figure 1 components for environmental performance evaluation (source: Kolk and Mauser, 2002)](image)

Based on environmental performance indicators, organizations need to collect both quantitative and qualitative data about each indicator, in order to evaluate organization’s environmental performance. Due to the evaluation’s results, different departments need to make changes and get improvement in their environmental performance.

### 3.1.2. Logistics system activities

Logistics can be expressed as a system consisting of the subsystems materials supply, production and distribution. It does not only consist of flow of materials, components and products which are processed and distributed to customers, but also include
supply chain flows of spare parts and return flows of defective and used products and packaging. The aim of logistics system is to supply customers efficiently with their required products (Jonsson, 2008).

As Wu and Dunn (1995) stated in “Environmentally responsible logistics systems”, the challenge of today’s logistics managers is to determine how to incorporate environmental management principles into their daily decision-making process. Different activities in a logistics system lead to different environmental impacts. Figure 2 shows how logistics decisions that affect the environment

![Image of logistics decisions diagram](source: Wu and Dunn 1995)

From figure 2, decisions which made in different activities in logistics system has directly or indirectly affected environmental performance. It is can be summarized from below categories:

- **Vendor selection and location.** Different vendors have different requirements for raw materials. Location also indirectly determines the environmental impact on delivering raw materials.
- **Warehousing.** The size and location of the warehouses directly result in disparate consumption in energy and land usage.
- **Packaging.** The materials used in packaging lead to different levels in wasting. Also it will show unlike weight in transportation.
- **Mode and carrier selection.** It is directly embodied in emissions through distribution channels both in inbound and outbound logistics.
- **Service level and network design.** Different service level and network distinguish the distance from distribution centers to the market. It also brings on distinct pollution and emissions to environment.
3.1.3. Flexibility in logistics systems

Flexibility enables stable performances under changing conditions; it has been defined as an attribute of a system technology for coping with the variety of its environmental needs. De Groote X. (1994) M. Barad and D. Even Sapir (2003) examined potential benefits of flexibility in logistic systems. Some attempts to define flexibility in logistic systems were collected in their research:

- Inter-organizational logistics flexibility
  The inter-organizational logistics flexibility is seen to be the key logistics activities. The degree of flexibility is determined by the size of choice set for executions and planning in the logistic dimension which consists of time, quantity and eventually packing and load carriers.

- Flexibility-like approaches in supply chains
  This attempt includes transshipment and postponement these two aspects’ study. Transshipment study is about how to enhance business performance by changing the means of transport during the journey and combine transportation hubs. Postponement is a business strategy that maximizes possible benefit and minimizes risk by delaying further investment into a product or service until the last possible moment.

3.1.4. Time-based logistics system

Time-based means have more requirement in customer-oriented. The companies should improve performance towards customers and become a customer-focused organization. (Persson G., 1995) In logistic field, Time-based mainly embody in distribution management. For example, the traditional distribution way in Europe is one or more warehouses in each country. For decreasing the distribution costs and increasing the customer service, the time based concept came into this field. The distribution way becomes the products are collected and directly delivered to customers all over Europe from one centralized warehouse. (Abrahamsson M., 1993) In this process, companies’ warehouses have no geographical advantage any more, but it is more important to deliver the products to the customers within a specified time.
3.2. Environmental impact on designing logistics system

3.2.1. Logistics system decision-making

Abrahamsson and Aronsson (1999) state that there are three main steps to consider when designing a new structure:

- Calculate the total cost and delivery service of the existing structure;
- Make calculations for alternative structures; and
- Make calculations on dimensions and size of facilities.

The first two steps stand on a structural level while the last step stands on a tactical or operational level. A decision-making model depends on human thinking and behavior; it can be influenced by many subjective factors, such as non-rational, emotional and unconscious. The following model shows a normal thinking way by most logistics managers who responsible for organizing and purchasing transports in each company.

![Schematic model of shippers’ logistical decision-making process (Source: Lammgård C., 2007)](image)

The activities in this running process include opinions-forming, forecasts-making, transports execution and improvement etc. Based on hierarchy model, how to connect logistics system decision-making and environmental performance will be illustrated in below sections.

3.2.2. The interface between logistics decisions and environmental performance

As the decisions which have influenced environmental performance discussed above, the complexity of logistics decisions and environmental effects have analyzed in Aronsson and Brodin’s research. There are four characteristics identified in
contributing to reduce the environmental impact of a logistics system.

*Increase fill rate (consolidation)*
There are two methods to increase fill rate. The first one is to change the logistics infrastructure. It can be shown in increasing the size of warehouses, centralizing distribution, reducing the number of warehouses, and changing the location of warehouses. The other way is to work more actively with vehicle routing, to change storage strategies on a regular basis, and to minimize the number of deliveries, which in some instances meant increasing lead-times.

*Standardization (physical)*
Standardizations in the physical system can be concerned in two levels: transportation vehicles and load carriers. Load carriers have to fit the vehicles. Due to standardization, it contributes to opportunities to increase the fill rates, which reduces the environmental impact.

*The importance of information for managing the supply chain (visibility)*
A new IT-system makes it possible to let a warehouse fulfill several different functions. It also makes it possible to change how each product is managed over time, and to move a product from being stored in one location to another location. The usage of IT-system also brings on increasing fill rate.

*Virtual warehousing*
It is embodied in the flexible understanding of transportation and warehouses. A specific function is coupled with a range of characteristics and mechanisms. It can be expected to reduce the environmental impact, reduce costs and increase delivery service.

To sum up, based on different logistics system decision-making levels as well as identified characteristics above, the characteristics and their interrelatedness are illustrated in figure 5. It is outlined obviously that any individual change in decision-making process can lead to the differences in the environmental performance of the system. Also, different decisions taken in a restructuring situation can strengthen each other, and each other’s effect.
3.3. Environmental Management System (EMS)

An Environmental Management System consists of a collection of policies, planning, implementation, operation, checking and management review affecting the entire organization and natural environment. (Brorson, T. 2006) An EMS includes the following activities: an environmental policy or plan, an introductory systematic assessment of the company’s operations and activities which affect the environment, quantifiable goals creation to reduce environment, resources providing, workers training, implementation progress checking through systematic auditing, and a management review, so that the companies can make corrections when it deviates from its goals or procedures. (Coglianese and Nash, 2001) And EMS can be generally described by figure 6.
3.4. ISO 14001

Once an organization implements an EMS, it may elect to have it certified to the ISO 14001 standard. Before the adoption of ISO 14000 standards, there were few environmental management standards, and certainly none that were recognized as consensus standards by all countries. The ISO 14000 standards lay out tools and system for the management of numerous environmental obligations and the conduct of product evaluations. International ISO 14000 standards were developed mainly in response to the proliferation of national EMS standards in various countries, which forced companies to deal with dozens of potentially incompatible systems from each country in which they conducted business. (Tibor, T. 1996) Specially, because of what is requires, ISO 14001 can be used as an indicator for the organizations and
enterprises to enhance their environmental protection through better environmental management. (Cascio, J. 1996) In the ISO 14000 series, ISO 14001 standard called a specification document, since it provides the specifications for an EMS. An organization must meet these specifications if it wants to become registered. ISO 14001’s adoption has to be certified by an independent third party auditor which helps the organizations and entreprises to ensure that the EMS conforms to the ISO 14001 standard meanwhile increasing the confidence from the customers and public.

ISO 14001, the foundation of the entire ISO 14000 series, is such a proactive environmental protection strategy in which regulatory compliance is but one of the elements of a more inclusive and all encompassing approach. ISO 14001, the environmental management system (EMS) standard, provides a framework to direct the use of organizational resources to full breadth of actual and potential environmental impacts through reliable management processes and a base of educated and committed employees. Regulatory compliance is now a normal result of this management strategy, along with awareness, sensitivity, and preparedness, greater reliability and consistency in meeting environmental objectives, and greater confidence in the organization’s ability to prevent accidents. The following overview structure in ISO 14001 indicates the way to implement the standard and includes the mechanisms that are needed to maintain and develop environmental work. It helps the companies reduce environmental risks by standardizing practices and promoting continuous improvement.

![Figure 6 Environmental Management System Model for ISO 14001. (Source: SS-EN ISO 14001:2004)](image-url)
3.5. Combination of EMS and logistics system

The emission rate is growing faster and faster these years. Transportation is the biggest part in logistic systems. At the same time, companies are active in cooperating with others in this fierce business world today. The control of suppliers is also a big problem for companies’ improvement of quality. So these two factors transportation and supplier are chosen to discuss in this thesis.

Transportation
Rao P. and Holt D. (2005) also summed up some environmental elements should be considered in logistic management from a transportation system such as type of transport, fuel sources, infrastructure, operational practices and organization:
- Environmental-friendly waste management.
- Environmental improvement of packing.
- Taking back packing.
- Eco-labeling.
- Recovery of company’s end-of-life products.
- Providing consumers with information on environmental friendly products and/or production methods.
- Use of environmentally-friendly transportation.

Supplier
Nawrocka D. (2007) wrote a paper for investigating the possibility of using environmental management systems (EMS) as a tool for the environmental management of supply chains, the use of EMS, the credibility of ISO 14001 and the role of supplier control in environmental management were analyzed. Since the companies adopted the outsourcing business, their supply chains are growing larger and much complex for facing the various suppliers. Supplier control is seen as a risk for companies’ environmental performance. The use of EMS is obviously showed in the relationship between buyers and suppliers. EMS would be not only improving the environmental performance from the internal environmental work, but also stretched to supplier outside the company’s limits meanwhile facilitating the communication between companies.
3.6. SWOT Analysis

SWOT analysis is a very efficient way of identifying strong and weak points and of examining the opportunities and threats of a certain area. The SWOT analysis is widely recognized and it constitutes an important basis for learning about the situation and for designing future procedures which can be seen as necessary for thinking in a strategic way. (Valles J. and Lozano M., 2004) The SWOT matrix is classified into four parts, strengths, weaknesses, opportunities and threats are established. In a strategic planning process, strengths and weaknesses are for the internal environment, opportunities and threats are for the external environment.

- **Strengths:** to analyze the resources and capabilities of the companies which are helpful to achieving the objective.
- **Weaknesses:** to analyze the harmful factors when achieving the objective.
- **Opportunities:** to explore the new opportunities with the external conditions.
- **Threats:** present the threats will meet in the changes of the external environment.

4. Description

4.1. Case description of Sandvik

Business in Sandvik Material technology (SMT) was the main part for the thesis study. Since 1862, Sandvik has developed into a global enterprise, with a multifaceted expertise in the filed of materials technology. As a global company, Sandvik’s goal is to improve customers’ productivity, consequently and profitability. The products and services offered by Sandvik shall provide maximum value to customers in terms of performance, quality, speed, safety, flexibility and total economy. Under the pressure
of social responsibility and customer need, how did Sandvik do to keep its sustainable development? Because of standardization, every business area in Sandvik should follow Sandvik’s way. We were expecting to get a general view for Sandvik group according to the case study of Sandvik SMT.

4.1.1. Description of logistics process in Sandvik SMT

With operations in 130 countries, the logistics function at every Sandvik business area has a very important mission. The main job of this logistic function is to manage the global shipments business. From the interview of the freight manager in Sandvik SMT gave us an overview picture of the process from finished goods to the supplier. With operations in 130 countries, the logistics function at every Sandvik business area has a very important mission. The main job of this logistic function is to manage the global shipments business. The freight management process is including capacity planning, purchasing and contracting; operational planning and Key Performance Indicators follow up. The process below is the distribution center process.

![Freight management and distribution center process in Sandvik SMT](Source: presentation from Lars Winges)

The area of freight management includes purchasing, contracting and contacting with the suppliers and distributors, suppliers control. Figure 8 shows the final part of the material flow in Sandvik SMT. The process of distribution starts from the finished
goods. When the goods from production department are ready for shipping they will be moved to the warehouse, and then the distribution center will be responsible to ship them to the customers. The packing notes with information about every goods will be done and physical package in their distribution center first. And then they will plan and book the shipment, as well as load the goods to the truck or container after that. The distribution center hasn’t owned the trucks or ships; they outsourced the transportation business and purchased this service for every shipment, but control the whole delivery process from finished good to the customer. The main responsibility of a freight manager is to contact suppliers, find the best supplier, analyze routes and volume for shipment planning, look for the new ways of transportation and new market, do cost analysis of the KPI follow up and make sure the suppliers accord with our requirement. Their mission is a highly strategy from a business standpoint, planning, and follow-up of SMT’s shipments for Sandvik’s global business. And they think total cost, high delivery precision and fast shipments are key competitive assets in aftermarket.

In the further conversation of the interview, the department hopes to own their own distribution system. This question has being thought all the time, but they think that it is difficult to change this situation. Because when to start working, there will be many factors have to be considered if want to improve something and the whole process is not owned by individual. The considering factors in this process consist of customers demand, service requirement, environment demand, market trend, price shipment and the total lead time etc. Fox example, if the price of air shipment increases, the department should go by boat, if the goods are valuable, they should shorter the lead time. A change will happen in these three or four years that Sandvik SMT is going to have a new system for the loading part which will be improved a lot at that time.

4.1.2. Sandvik environmental management system

The statistics of Sandvik annual report 2008 showed that the number of major production, service, machinery rebuilding and distribution units certified in accordance with the international standard environmental management system, ISO 14001 is 147(82%). Sandvik’s target is that all major production, service and distribution units shall be certified with two years of their acquisition or establishment. (Sandvik annual report, 2008) According to the information collected from Sandvik’s website and the interviews, Sandvik’s EMS was described by following the structure.

Environmental aspects
Sandvik is a big industrial manufacture company. From the process of manufacturing, many aspects have the influences on the environment, including the use of raw materials, use of energy, consumption of fresh water, biodiversity, emissions and waste. The emissions are a key focus for Sandvik’s environmental management systems. Because the emissions from Sandvik’s operations vary in nature, the primary
substance emitted is the carbon dioxide to the atmosphere. Carbon dioxide is the greenhouse gas which highly concerned by human being nowadays.

**Environmental policy**
Sandvik has a series of specified policy for environment and also lists it on its website.

“

- Issues concerning the environment, health and safety are included as integral parts of Sandvik’s overall operations. Continuous improvements are achieved in these areas through management by objectives. Sandvik considers that the greatest effects are reached through preventive action.
- Sandvik pursues an approach that leads to long-term, sustainable development. This means that Sandvik strives to achieve high efficiency in the utilization of energy and natural resources, to support systems for materials recovery and recycling and to prevent or limit pollution.
- Sandvik strives to offer work conditions that stimulate its employees to work effectively, assume responsibility and continue to develop their total competence.
- Sandvik shall fulfill or exceed environmental demands mandated by law, regulations and international agreements. Sandvik believes that uniform and environmentally effective requirements and standards should be established at the international level.

”

(Sandvik annual report, 2008)

**Environmental objectivities and targets**
Based on the environmental aspects, the objectives have been set by Sandvik:

- Reduction of energy and raw materials consumption
- Reduction of emissions to air and water
- Increase in materials recycling, both internally in the manufacturing processes and externally by recycling of our products.

Because of the key environmental factor carbon dioxide and its uncertainty, a new target was set to reduce carbon dioxide emission by 10% from internal use of fossil fuels and electricity and commence reporting of carbon dioxide emissions arising from transportation (passenger and freight) by the end of 2009. (Sandvik annual
Implementation of EMS and Audit

Sandvik has a specified department for environment which organizing the relevant environmental issues in Sandvik’s business performance, like evaluating the environmental aspects, holding the training program and collecting the environmental reports. Sandvik has both internal audit and external audit to evaluate Sandvik’s internal environment and control their suppliers’ environmental performance.

Continuous improvement

Sustainability is an important part of the Sandvik’s business activities. Sandvik has been conducting extensive sustainability efforts for many years and reports the results of these efforts in his sustainability report. In the sustainability report 2008 and the described before, we can found that Sandvik controlled its environmental performance accordance with figure 6 environmental management system model for ISO 14001. This process is a circle and the finally result is continuous improvement.

4.1.3. Interaction between logistic process and EMS in Sandvik

SMT

Because the main logistic activity in the freight management department is transportation, and the emission is considered to be the key environmental aspect in Sandvik. Although Sandvik outsourced this activity, Sandvik should also consider their supplier environmental performance. Environmental problems most often have roots far earlier than at the final production stage, and it is important to recognize this fact and take appropriate measures. Sandvik think that they should establish and maintain appropriate procedures to evaluate and select the best suppliers and subcontractors on their ability to meet their requirements. They created a proper system of communication with suppliers and a system of supplier control.

The staffs in the freight management department in Sandvik SMT think that they are concerning about environment and keep improving all the time. But the environmental knowledge becomes an essential issue to get improved. The following, the most part of environmental influences are generated by the transportation; to control their supplier’s environmental performance is what Sandvik need to operate first. For example, slower products are environment-oriented meanwhile lead time has to be increased. How to balance these two aspects are considering by Sandvik SMT all the time.

The suppliers of Sandvik SMT are required to have a general emission report for shipment. Except the emission reports, Sandvik SMT has the supplier evaluation tool
including quality, measurement, complain handling, environment, information and contracting etc. The sample of questions about what will Sandvik SMT asks their supplier by evaluation tools is attached as Appendix 3. The freight management department in Sandvik SMT employed a specified person response for environment issues this year; the main job of this person is collecting environmental data.

4.2. Case Description of FLB

FLB is a growing third party logistic company focusing on the telecom- and electric industry sector. As a local company, how did FLB view the environmental problems? As a supplier to many global companies, such as Ericsson, what did FLB do to fulfill their customers’ requirement?

4.2.1. Logistic system in FLB

In FLB, the main logistic activities happen in the inbound logistic which running like the figure below:

![FLB Inbound logistic activities](image)

Figure 9 FLB Inbound logistic activities. (Source: authors adapted from the interview)

For example, FLB delivers the big products from Ericsson every two hours into Ericsson’s production. The trucks in FLB transport the Ericsson material from warehouses to production to warehouse circularly. Some of the products are unpacked before delivery. Ericsson’s finished goods before they go out to the world are stored in FLB. FLB also store packing material for Gevalia coffee, daily deliveries into production.

4.2.2. Environmental situation in FLB

From the news of FLB website shows that FLB has more consciousness today. (FLB, 2009) From the interview with the logistics manager, we knew cost efficient was still the priority in their business consideration. Although there is not so much requirement from their customers on FLB’s environmental performance, FLB decided to get the ISO 14001 certification next year for the social responsibility. But the difficulties for certifying are lack of knowledge about environment protection and proactive planning.
4.3. The comparison between Sandvik SMT and FLB

Sandvik SMT and FLB are the case companies in our thesis study. One is a global company which is proactive for its sustainable development. It has a lot of completed requirements for its internal management and external management, such as the evaluation for their suppliers. The other is a local company which mostly acts like a supplier to many global companies, the main activities for its business depend on its customers need. However, the same similarities for both of them are cost efficient is always the first factor to consider and environmental issues are kept firmly in mind all the time.

<table>
<thead>
<tr>
<th>Background</th>
<th>Sandvik SMT</th>
<th>FLB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of industry</td>
<td>Manufacturing</td>
<td>Service</td>
</tr>
<tr>
<td>Time of Establishment</td>
<td>2003 (Sandvik: 1962)</td>
<td>1989</td>
</tr>
<tr>
<td>Ownership</td>
<td>Joint stock</td>
<td>Family owned</td>
</tr>
<tr>
<td>Number of Employees</td>
<td>8600</td>
<td>60+temp</td>
</tr>
<tr>
<td>Yearly Turnover (2008)</td>
<td>19,300M SEK</td>
<td>58M SEK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Layout</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of corporation</td>
<td>Global</td>
<td>Local</td>
</tr>
<tr>
<td>Location of head office</td>
<td>Sandviken, Sweden</td>
<td>Gävle, Sweden</td>
</tr>
<tr>
<td>Geographical distribution</td>
<td>130 countries</td>
<td>3 main locations in Gävle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Business filed</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of business</td>
<td>Materials technology</td>
<td>Third party logistic</td>
</tr>
<tr>
<td>Production or service</td>
<td>Tube; Strip; Wire; Kanthal; Process systems; MedTech.</td>
<td>Basic service: Inbound Handing; Storing; Outbound Handing; Bonked warehouse; Customer administration; Stock and transaction reports. Value-added service: Production; Quality support; Reverse logistic; Garbage disposal service.</td>
</tr>
<tr>
<td>Suppliers and customers</td>
<td>Main suppliers:</td>
<td>Main customers:</td>
</tr>
</tbody>
</table>
Geodis Wilson; DSV DHL | Ericsson GEVALIA

| Environmental solution | The adoption of EMS (ISO 14001) | 82% units of Sandvik have been certified by ISO 14001 till 2008. | Plan to get the certification of ISO 14001 in 2010. |

Table 2 Comparison between Sandvik SMT and FLB (Sources: Sandvik 2009, FLB 2009, Interviews)

5. Analysis

In this part, we aim to analyze the case companies based on theories and models which illustrated before. The conflicts between theories and practice will be discussed in the next part.

5.1 Logistics effect on environmental performance

5.1.1 Reasons for less environmental attention on logistics system

As discussed before, there are many indicators to evaluate environmental performance, such like energy consumption, water consumption, greenhouse gas emissions, and total waste, etc. Since the annual report showed by Sandvik AB, the environmental key performance indicators are categorized into six groups:

- Energy consumption
- Raw material consumption
- Fresh water consumption
- Emissions to air and water
- Waste
- Hazardous chemicals (Sandvik SMT website).

Based on these indicators, it is shown that most environmental aspects are affected by product manufacturing part in Sandvik SMT. The company makes lots of effort to improve the situation, such like making changes in product and process development. Since EMS has implemented in Sandvik SMT, it also has clear environmental policy and improvement objectives in production process, such as increasing in materials recycling, both internally in the manufacturing processes and externally by recycling of products. Logistics as another important system in the whole company, it also has
big effect on environmental performance. Differing from manufacturing part, although logistics is under the same umbrella of ISO 14001 with manufacturing, there are not many changes or developments in logistics systems. Why there is less environmental attention on logistics system? The reasons for this situation can be identified in three aspects.

Firstly, logistics system is comprised by different activities, in order to link each component on supply chain. It differs to manufacturing part which consisted by product flow lines. Manufacturing can be one integrated component in supply chain while logistics system distributes their activities in dissimilar positions of supply chain. Each activity has independent and unlike impact on environment. For instance, transportation has impact most on emissions to air. But warehousing most affect on land use and energy consumption. Different logistics systems have distinct activities, so uncertainty exists in logistics systems. It is not obvious and accurate for enterprise to collect data for evaluating environmental performance. Secondly, changes are hard to be implemented in the logistics system. As logistics systems help materials flow in the whole supply chain, each activity needs to connect with each other closely. If there are some changes exist in one component, the influences will spread around like butterfly effect. It is risky for enterprise make changes in different components at the same time. At last, as the development of third party logistics, many companies choose to outsource their logistics business to the third party logistics company. For example, Sandvik SMT buys transportation service from many suppliers, such as Geodis Wilson and DHL. Due to logistics activities are divided into different pieces, the manufacturing company may take less care on environmental performance on their logistics system. Meanwhile, take FLB as an example, it plays third party logistics role in the supply chain, but it doesn't have ISO 14001 as well as EMS. In some environmental issues, it doesn't need to meet international standards. In this case, environmental responsible is easy to be transferred between suppliers and buyers. It leads to lack development in environmental impact through changing logistics system.

5.1.2. Optimizing logistics system contributes to environmental improvement

It is acknowledged that logistics plays important role in supply chain management. With more and more cost spent in logistics part, all companies tried to decrease total cost through redesigning and restructuring their logistics systems. But at the same time, as highlight in cost spent in logistics part, environment issues are not easily implemented and managed through logistics system. Why and how optimizing logistics system can contribute to environmental improvement? The reasons are described as below.
Logistics activity effect on environmental indicators

Above outlined before, logistics system distributes their activities in dissimilar positions of supply chain. It includes transportation, warehousing, inventory management and packaging etc. Due to logistics activities link with unique component in supply chain, the influences to environmental impact are also flowed with material.

In our case, since two companies have different nature and policy, they have unlike logistics activities. Also they have different standards and ways for the data collecting. As a buyer, Sandvik needs to set standards and requirements for outsourcing its transportation business. In Sandvik SMT, they have high level of environmental requirement from their suppliers; all suppliers will provide environmental performance data to the distribution department in Sandvik SMT, in order that its distribution department can outsource their shipping to most suitable suppliers. Oppositely, FLB as a third party logistics company without ISO14001, it doesn't have to follow the international standard. But it needs to collect data by itself, in order to satisfy its customer’s demand. From this perspective, Sandvik SMT and FLB both have their indicators and measurements to evaluate their environmental performance. They agree that logistics activities have big influence to environmental impact as well. According to the annual report by Sandvik AB, the environmental indicators for Sandvik AB collected are listed in table 3. From the interview, FLB also collected data in emissions to air. Figure 1 in the theoretical framework part shows that which logistics activities affect on listed environmental indicators as well.

<table>
<thead>
<tr>
<th>Environmental Indicator</th>
<th>Company</th>
<th>Related logistics activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption</td>
<td>Sandvik SMT</td>
<td>Warehouse management/Loading goods</td>
</tr>
<tr>
<td>Raw materials consumption</td>
<td>Sandvik SMT</td>
<td>Package</td>
</tr>
<tr>
<td>Fresh water consumption</td>
<td>Sandvik SMT</td>
<td></td>
</tr>
<tr>
<td>Emissions to air and water</td>
<td>Sandvik SMT/FLB Logistik AB</td>
<td>Transportation</td>
</tr>
<tr>
<td>Waste</td>
<td>Sandvik SMT</td>
<td>Package/Transportation</td>
</tr>
<tr>
<td>Hazardous chemicals</td>
<td>Sandvik SMT</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Logistics activities effect on environmental indicators (source: authors adapted from discussion)

From table 3, it is showed that environmental performance is influenced by related logistics activities, especially by transportation and package. If companies optimize related logistics activities which exist in the whole system, the environmental impact on logistics system will be decreased. And transportation and package should be prior to consideration.
**Flexibility in logistics system**

As described in theory part, inter-organizational logistics flexibility is the key logistics activities specified and ordered by one set of actors belonging to the logistic channel. There are two basic flexibility types associated with supply/demand relations and can be measured on a range dimension. They are: flexibility of a transportation tool and flexibility of a transportation network (Barad and Sapir, 2003). It suggests that as logistics activities differs from manufacturing part by flexibility; different decisions made on logistics system will lead to disparate environmental consequences. And the flexibility mainly embodied in transportation sector.

From the interviews, the theory gets to be proved in both two companies. They both admitted that transportation system has most environmental impact on emissions to air. But it is also flexible to change. From flexibility of a transportation tool perspective, they can decide different modes to accomplish transportation business, such like by truck, train, flight or ship, etc. On the other hand, different network is embodied in having own transportation system or outsourcing transportation business to another agencies. Take Sandvik SMT as an example, it buys transportation service from different suppliers, but unique supplier has its own environmental requirement. The final environmental performance depends on which supplier Sandvik SMT chooses, it also brings different environmental consequences.

To sum up, due to logistic activities work on the environmental performance, optimizing logistics system can contribute to environmental improvement. Meanwhile, as flexibility in logistics systems, decision-making on designing logistics system influences different results in environmental performance. The flexibility is most reflected in transportation sector; so that transportation effect on environment should be prior to be considered when design the logistics system.

**5.2. The environmental impact on designing logistics system**

Part 5.2.1 mainly describes how organizations have done due to getting improvement in environment-oriented logistics system.

**5.2.1. Improvements in environment-oriented logistics system**

Sandvik SMT as a worldwide company with both ISO14001 and EMS, it has got improvement in environmental performance by ameliorating its logistics system in many ways. Meanwhile, although FLB as a third party logistics company without neither ISO14001 nor EMS, it still highlights taking environmental issues in both work environment and others, in consideration when they decide about investments (FLB website). But no matter Sandvik SMT or FLB, the changes due to environmental improvement are not outstanding. There are some methods used in
both two companies.

Centralization
In FLB, there are only three plants located in Gävle. All inbound goods from its suppliers will be transported to the whole Sweden, even the whole world. Benefits from centralization can be seen in three aspects: shorten lead-time, cost reduction and environmental improvement.

In Sandvik AB, changes in distribution center are firstly found in Coromant part. Due to the freight manager in Sandvik SMT has not given us much information about its distribution centers, the materials about Coromant distribution center are found in other articles. Before the centralization there was at least one warehouse in every sales company and two central warehouses in the distribution system, one in Sweden and one in Holland. The change of the distribution system started in 1982 with their DD-system, Direct Distribution of customer addressed deliveries from the central warehouses to the local sales companies (Abrahamsson, 1993). From time aspect, it facilitates time-based logistics by shortening lead-time to customers. But from environmental aspect, it decreased numbers of warehouses, in order to decrease the land use and energy consumption in distribution centers. Benefits to environment can also be found in transportation system. Since DD-system has been used, it increased the fill rate, so that efficiency of transportation has been improved; the total emission has been reduced.

Information technology (IT) development
As information technology develops better and better, many advantages are emerging. It helps environmental performance get improvement as well. Firstly, information technology is widely used in inventory management and distribution system. It makes data more accurate, in order to reduce waste made in logistics system. Secondly, it makes communication more convenient. For instance, people work in different department doesn’t need to use telephone or hold meetings for communication. E-mail or online chat tools can reach the goals, in order to reduce the emissions, energy consumption (electricity) and waste. In addition, as the development of warehousing management system (WMS), the whole warehouse can be managed by computer systems without people. It goes down the waste as well as emissions in warehousing, even in the whole logistics system.

Standardization (physical and documental)
In FLB, the tracks are made in standard size. As introduced by the logistics manager, it increases accuracies when make decisions on designing logistics system. It contributes to opportunities to increase the fill rates, which reduces the emissions to the air. In Sandvik SMT, environmental requirements have been documented; employees who work in Sandvik SMT need to follow the disciplines. Each activity also needs to meet standard requirements. Environmental improvement can be seen
obviously by standardization.

In conclusion, the improvements in environment-oriented logistics system which exist in two case companies can be summarized as above three aspects: centralization, IT development and standardization. But as different natures of two companies, Sandvik SMT has also got improvement in evaluating environmental performance to their suppliers. This will be illustrated later.

### 5.2.2. Environment-oriented logistics system decision-making

As Rodrigue (2001) cited in the article, green paradoxes of logistics have been identified in various dimensions:

- **Cost** (environmental costs are often externalized)
- **Time/flexibility** (extended production, distribution and retailing structures consuming more space, more energy and producing more emissions)
- **Network** (concentration of environmental impacts around major hubs and along corridors)
- **Reliability** (modes used are the least environmentally efficient: trucking and air transport)
- **Warehousing** (inventory shifted in part to roads contributing to congestion and space consumption)

In the interview, the managers who work on the logistics part in each company also gave the factors which need to be considered into logistics system decision-making. The factors are listed in Table 4.

<table>
<thead>
<tr>
<th>Name of the company (Nature)</th>
<th>Sandvik SMT (Manufacturing Company)</th>
<th>FLB (Third-party Logistics Company)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors considered in logistics system decision-making</td>
<td>Cost</td>
<td>Customer requirement</td>
</tr>
<tr>
<td></td>
<td>Customer demands</td>
<td>Total cost and cost efficient</td>
</tr>
<tr>
<td></td>
<td>EMS documentation demands</td>
<td>Lead-time</td>
</tr>
<tr>
<td></td>
<td>Market trend</td>
<td>Environmental demand</td>
</tr>
<tr>
<td></td>
<td>Total time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plant location</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Business model</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4 factors in logistics system decision-making (source: interview with two companies)*

Compared with Rodrigue’s theory, companies in practice attach importance to customer demands more. Although cost is still prior to be considered into
decision-making process, there are more concerns brought into environmental demand. By combining with the model described in the theoretical part, those influential factors become the motivation for logistics system design. Based on empirical findings and theoretical framework, the proposed model for environment-oriented logistics system is summarized in figure 10, which is an extension of the original model.
Figure 10 Proposed model of environment-oriented logistics system decision-making process (authors adapted from Lammgård, 2007)
5.3. Outcomes and Challenges of implementing EMS in logistics system

5.3.1. SWOT Analysis of implementing EMS in Sandvik SMT logistics system

To explore the outcomes and challenges of implementing EMS in logistics system, SWOT analysis is used in this thesis. According to FLB hasn’t used EMS yet, in this part, the SWOT is only used to analyze Sandvik SMT. The benefits and challenges will be listed according to the SWOT analysis as well as the results from FLB.

When elaborating the SWOT matrix the favorable and unfavorable aspects are established regarding the development of the area, while distinguishing the internal and external variables. That is, strengths, weaknesses, opportunities and threats are established. On one hand, negative factors are grouped together with respect to challenges and possibilities of development, i.e., weaknesses (internal elements that cannot be modified in the short-term) and threats (external elements). On the other hand, positive factors for internal benefits and further development are shown, i.e., strengths and opportunities, internal in the former case, external in the latter (Lozano and Valles, 2007). The SWOT analysis of implementing EMS in Sandvik SMT is showed in Table 5.

<table>
<thead>
<tr>
<th>STRENGTHS (INTERNAL FACTORS)</th>
<th>WEAKNESSES (INTERNAL FACTORS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>● High consciousness of environmental protection results in cost efficient from accurate planning. It reflects on increasing the fill rate of transportation or decreasing the cost in energy consumption.</td>
<td>● Nature of the product leads to consuming of hazardous chemicals and any amount of energy.</td>
</tr>
<tr>
<td>● Reverse logistics system facilitates to save the raw materials.</td>
<td>● Lack of professional knowledge about EMS.</td>
</tr>
<tr>
<td>● Development of IT helps reduce cost in human resource (e.g. automated warehouse).</td>
<td>● No special financial budget for implementing EMS in the early stage.</td>
</tr>
<tr>
<td>● Good working environment decrease the risks in employees’ health.</td>
<td>● Conflicts exist between customer demands and environmental requirements.</td>
</tr>
<tr>
<td>● Build good brand by early advocating</td>
<td></td>
</tr>
</tbody>
</table>
EMS and ISO 14001 in Sweden.

<table>
<thead>
<tr>
<th>OPPTUNITIES (EXTERNAL FACTORS)</th>
<th>THREATS (EXTERNAL FACTORS)</th>
</tr>
</thead>
</table>
| ● Disseminating EMS and ISO14001 will be a trend around the world. The company will win more support and respect from the society.  
● New product/process development in reducing the environmental impact.  
● Flexibility in logistics system design (mainly embodied in distribution supplier and transportation mode chosen).  
● Owning transportation service by SMT itself.  
● More cooperation with other branch companies in Sandvik (e.g. SMC and Tooling) | ● Higher environmental requirements from EMS and ISO14001 causes more cost in environmental maintenance.  
● More competitors will also build corporation brand by having EMS and ISO14001.  
● More environmental pressure from standards may lead to companies escape environmental responsibility by outsourcing.  
● Increment of tension between human activities and environment. |

Table 5 SWOT Analysis of implementing EMS in Sandvik SMT (source: authors adapted from interviews)

5.3.2. Outcomes of implementing EMS in Sandvik SMT logistics systems

To get the benefits from implementing EMS through logistics system, Sandvik SMT distribution department mainly takes actions from two ways. One way is to use
supplier audits; the other one is to sign “Clean Shipping Project” with several Swedish cargo owners. The audit tool they use has high environmental requirement from their suppliers. Meanwhile, the “Clean Shipping Project” pushes pressure to transportation business providers. Based on the SWOT analysis, benefits from implementing EMS in Sandvik SMT can be summarized into following points.

**Optimizing the resource**
As the vice president Anders Wallin replied in the interview, environmental logistics systems are usually effective because they lead to better utilization of resources. The results can be achieved by increasing the fill rate in the transportation system, implementing reverse logistics, decreasing energy consumption and automation of warehousing, etc. The results are reflected on both raw materials and human resource.

**Decreasing the risks in human health**
Due to the nature of product in Sandvik SMT, getting environmental improvement by EMS will reduce the rate of accidents happened in the loading goods sector. As well as decreased usage of hazardous chemical, it provides employees healthier working environment.

**Building better brand**
From corporate perspective, early advocating EMS and ISO 14001 is good for building corporation brand. It facilitates to launch market. Also it attracts more suppliers to provide more environmental business.

### 5.3.3. Challenges for implementing EMS in Sandvik SMT and FLB logistics system

As EMS is widely used around the world, it brings lots of environmental improvements as well as benefits to the corporate performance. Meanwhile, companies face challenges of implementing EMS. For Sandvik SMT, they haven’t met difficulties when applied for ISO 14001, but problems exist during maintaining process. At the same time, FLB is going to apply ISO14001 in 2010. It also faces obstacles during the applying process. The challenges are described as below.

**Conflicts between customer demands and environmental requirements**
As customer-oriented marketing develops, to satisfy customer demands becomes the first factor for making companies’ strategy. Regarding to the description of time-based logistics system in theoretical framework, customers attach more importance to time issue than any other issue. Time issue becomes core competitive advantage in the supply chain.

As need for shortening lead-time increase, more pollutions and emissions will be
existed. It brings challenges to EMS. For instance, in order to win competitive advantages by short lead-time, companies prefer flights or trucks than railways. According to statistics, flights and trucks will make more pollutions and emissions to environment than any other transportation mode. It brings conflicts between lead-time from customer demands and transportation mode from EMS requirements.

**Conflicts between cost efficiency and environmental cost**
For most companies, cost efficiency is the goal for corporate strategy. To maximum the profit is not only reached by selling product or service as much as possible, but also by reducing the total cost. From the interviews, Sandvik SMT distribution department and FLB both have no budget for environmental investment. Although Sandvik SMT has implemented EMS, the budget only for corporate level, there is no special budget for distribution department. Environmental budget on logistics system can only be the external and unexpected cost for the whole department. The limited cost issue also happened to FLB. So far, they don't have any financial plan for environmental improvement. Even the customer has environmental requirements; the cost should be added into price to customers.

**Lack of environmental knowledge**
The challenge about lacking environmental knowledge appears into both companies as well. When EMS is implemented in a company, the objective is not only to improve environmental consciousnesses, but also to spread professional knowledge. For both logistics managers, they stated that dissemination of environmental knowledge is the biggest obstacle for implementing EMS in improving consciousness among employees. As the freight manager in Sandvik SMT said, he can get the emission data and knows that decreasing the emissions is important, but he has not enough knowledge to understand those data. Even there is one environmental export works in the distribution department; the professional knowledge is still accepted by the whole department slowly. Based on above, having environmental training is an important factor to implement EMS.

Above all, implementing EMS into logistics system brings benefits to companies by controlling suppliers and committing “Clean Shipping Project”. At the same time, the challenges also exist. The next section will illustrate more by dealing with this analysis.
5.4. The conditions for using EMS

5.4.1. Comparison of motivations for having ISO 14001 between Sandvik SMT and FLB

Regarding to the described contents before, Sandvik SMT as a worldwide manufacturing company, many reasons motivate it to get ISO14001 and implement EMS. Meanwhile, FLB as a third party logistics company, which factors stimulate it strive for having ISO14001? The motivations compared between two companies are analyzed from external and internal ways, which are shown in table 6.

<table>
<thead>
<tr>
<th>EXTERNAL MOTIVATIONS</th>
<th>Sandvik SMT (Manufacturing)</th>
<th>FLB (Third Party logistics supplier)</th>
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<tbody>
<tr>
<td></td>
<td>▪ More and more concerning about environmental issues from society, such like citizens, government, etc.</td>
<td>▪ Social responsibility in environmental protection</td>
</tr>
<tr>
<td></td>
<td>▪ To justify sustainable development</td>
<td>▪ More restrict environmental requirements from customers</td>
</tr>
<tr>
<td></td>
<td>▪ To satisfy customer demands</td>
<td>▪ Social pressure</td>
</tr>
<tr>
<td></td>
<td>▪ Corporation citizenship issue</td>
<td></td>
</tr>
<tr>
<td>INTERNAL MOTIVATIONS</td>
<td>▪ Lack of professional environmental knowledge leads to needs for training from EMS.</td>
<td>▪ Better utilization of transportation tools and warehouse space</td>
</tr>
<tr>
<td></td>
<td>▪ Standardize EMS by external audits</td>
<td>▪ Social responsibility from internal employees</td>
</tr>
<tr>
<td></td>
<td>▪ Senior management requires ISO14001 to build corporation brand.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ Better utilization of resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ To provide healthier working environment for employees</td>
<td></td>
</tr>
</tbody>
</table>

Table 6 Comparison of motivations for having ISO 14001 between Sandvik SMT and FLB (source: authors adapted from interviews)

From the comparison, it is shown that for worldwide manufacturing company Sandvik SMT, the motivations for getting ISO 14001 are both from internal and external. But internal factors facilitate more in stimulating corporation to get it. For third party logistics supplier FLB, since they don't have formal EMS, they have not realized how many benefits EMS can bring to the company. Hence the motivations for getting ISO 14001 are mostly from social responsibility in environmental protection. Based on
different motivations from Sandvik SMT and FLB, different conditions for using EMS in manufacturing and logistics suppliers are described in the next section.

5.4.2. Comparison of EMS using conditions in manufacturing and supplier companies

Above all analysis before, manufacturing companies and logistics suppliers motivate to get ISO14001 from different ways. As the difference between driving force, the conditions of implementing EMS are also not the same.

For manufacturing companies, due to driving force are most from internal environment, the company itself can realize EMS brings benefits. The conditions should be considered from the resource companies have and the improvement companies reach. For those companies which have used EMS, maintenance is the most important issue brought into thought.

For service supplier companies, motivations are most from external environment, whether the company implements EMS is depends on how much demands from society and customers. The conditions are considered from customer environmental requirements and the cost companies will spend. Popularization environmental knowledge is something that is prerequisite.

6. Discussion

6.1. Conflicts between theory and findings

As the theory described, EMS has a series of high requirements to evaluate the environmental performance. As it is required, knowledge training is an essential part to implement EMS. But after the interviews, lack of knowledge becomes biggest problem. Also from the view of cost efficient, the conflicts are obvious. For the senior management, cost efficient can be embodied in the utilization of resources. But for operational departments, environmental cost is not easy to be balanced. Especially for the supplier company, such like FLB, cannot easily make budget for environmental improvement. The main motivation is from the employees’ social responsibility and corporation citizenship. Ems is too heavy on slogans and light on results. That's the biggest conflict between theory and findings after the research.
6.2. Change management in practice

Based on two interviews, both case companies stated that changes are hard to implement. To implement a change, many factors need to be considered. Firstly, cost is core issue. For an enterprise, cost is not enough at any time. How to balance the cost for environmental change and the benefits from the change should be evaluated before the change. Secondly, the ownership is also a factor. Changes cannot be easily implemented in each department; it needs to be confirmed from top management. The implement process of change management is not easy as well. Like implement EMS in Sandvik SMT, although it sets policy, objectives, the process is not as expected. Many obstacles exist in the change process.

6.3 Problems in outsourcing

The problems in outsourcing can be illustrated as outsourcing doesn't mean escaping environmental responsibility. For a company which has ISO 14001, it should have high environmental requirements to suppliers, in order to increase total environmental performance through supply chain. As described before, environment-oriented logistics system design should be considered in a supply chain view.

7. Conclusions and Recommendations

Through the research, the main logistic activities in Sandvik and FLB were described as warehouse management, package and transportation. The environmental influences results from these three activities include energy consumption, raw material consumption, waste and emission to air and water. Especially, the transportation and package factors should be the prior to consideration. When combining the environmental issues with logistics to study, an interacting effect between them will be found. The logistic activities impact the environment, the environmental thinking is leading the changes of logistics system design in the meanwhile. For decreasing the land use and energy consumption, many warehouses are removed and one central warehouse instead. The direct distribution way has begun to act as a leading role in many global companies’ logistic business, the centralization of warehouse management also facilitates the application of time-base logistics. To a certain extent, the fill rate has been improved and the total emission can be controlled in this process. The development of IT solutions such as WMT is the results from decreasing the energy consumption in the inventory and distribution. And the environmental factors can also influence the logistics system decision-making.

The considerations of logistics system decision-making which both mentioned in Sandvik and FLB consist of cost efficiency, customer demands and requirements, lead
time and environment demand. Cost is always the number one factor for both companies to consider, no matter the company has the EMS documentation demands or without ISO 14001, they all think that environment factor should be kept in mind all the time. On one hand, the companies improve the environment through enhancing inter-organizational logistics flexibility and transportation tools and networks. On the other hand, they adopt the environmental management system to standardize themselves.

One result from the interviews is that the effects of using EMS in logistics system is not obvious in production system. Because there are many uncertainties in logistics system, each component has the different environmental influence. These components are closely connected in the whole supply chain and are hard to be change. To some manufacturing companies, the logistic business is outsourced, this make them less care on environmental performance of their logistic system. The conflicts with customer demand and cost efficiency and knowledge lack when using EMS are the unsolved problems for the companies all the time. However, EMS is helping the companies optimizing the resource, decreasing the risks in the human health and building better brand. And one more result from the interview which can not supported by enough quantitative methods in the thesis study is that the companies usually think that to maintain the internal environmental work means lead to better utilization of resources, the effective systems are formed and the total costs will be decreased.

The recommendation for these companies is to enhance the knowledge of environment no matter from the internal education or external training program and strengthen the transportation and suppliers management, like to change the type of transport, fuel sources and infrastructure, operational practices and utilize the EMS in supplier control meanwhile have a better communication between each other.

8. Future Study

The target of this thesis is to explore the implementation of EMS in logistic system. The first case company Sandvik is a manufacturer, the second one FLB is a supplier. These two cases are not enough to show the whole logistics activities in a logistic system. More research is needed, to analyze the logistic activities of a company which acts like a retailer can complement the thesis study.

For an in-depth study of the possibilities in those challenges of implementing EMS, such as cost efficient. The more quantitative researches are needed to enhance the data collection for the analysis of environmental management system.
References


The Intermodal Road-Rail Case. BAS Publishing Göteborg, pp109


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Appendix 1

Environment-oriented Logistics System Design
Interview Question List
Sandvik

The purpose of our paper is to see the potential possibility in integrating environment issues into logistic system design. And the research questions are listed as follow:

- Describe how activities which exist in logistics systems interact with environmental performance and examine the fundamentals of designing environment-oriented logistics system.
- Considering the EMS role in logistics system, explore results and challenges for implementing EMS in practice.
- Whether it is possible to fulfill cost efficiency and environmental responsibility at the same time and provide some insight about the framework for undertaking EMS.

Describe the major job you work with. How is your business going? (General information)

Logistics System
1. Considering your department, what position do you think your department stands in the materials flow? What comes into your department and what goes out from your department?
2. Please describe the activities/ components you work within the logistics system.
3. The goals for Sandvik AB to design its logistics system.
4. The steps in designing logistics system.
5. Which factors needs to be considered when design its logistics system?

Environmental Performance
6. How do you think environmental issues can help Sandvik AB get competitive advantages?
7. According to your annual report, how do you evaluate environmental performance? How do you get the data in different indicators?
8. How much money (the percentage of the budget) have you investigated in improving environmental performance?
9. What have you done in improving employees’ consciousness in environmental issue?
10. Do you have environmental requirements to your suppliers? If it has, how to measure and control the environmental performance to your suppliers?
The environmental impact on designing logistics system

11. In logistics system, what have you changed to decrease the environmental impact in each activity (the activities you mentioned before)?
12. As we see on Sandvik website, “There are three methods: optimizing processes, reusing material and finding external application areas.” How these three methods done with the logistics system? Can you give us some examples?
13. How does Sandvik AB balance the total cost in logistics activities and environment (how to balance the money which cost in improving environment)?
14. Whether Sandvik AB has reverse logistics. If it has, please describe the benefits and obstacles in reverse logistics.

The implementation of Environment Management System (EMS) in logistics systems

15. Which rules and regulations you need to follow to sell your product?
16. When Sandvik AB got ISO14000 Certification and what motivated Sandvik AB to get it. How is the adoption going so far? What about the situation in Sandvik Material Technology?
17. Which difficulties have you met when you applied for ISO14000 certification?
18. How EMS is implemented in logistics system.
19. How does Sandvik affect the environment (in logistic activities) and which requirement must Sandvik meet?
20. How does Sandvivk view the environment by looking Sandvik’s environmental policy, reflections and indicators?
21. Which are the key environmental factors (in logistic system) do you think must be improved first? How is Sandvik’s objectives and target in EMS? (7)
22. Does Sandvik have a specialized department for environmental management? Who works for that? Is it necessary to employ a professional person to participate in evaluating the environmental issues?
23. How can Sandvik improve? What is the advantages of using audits (for logistic system)? What is the responsibility of internal auditors and externals auditors?
24. Please describe the difficulties in implementing EMS.
25. What are the benefits on using certification or EMS to control the logistic system?
Appendix 2

Environment-oriented Logistics System Design
Interview Question List

FLB

Logistics System
1. Please describe the activities FLB Logistik AB has in its logistics system.
2. The goals and steps for FLB Logistik AB to design its logistics system.

Environmental Performance
3. How do you think environmental issues can help FLB Logistik AB get competitive advantages?
4. Whether FLB Logistik AB has measurements or indicators for evaluating environmental performance in logistics system.

The environmental impact on designing logistics system
5. In logistics system, what have you changed to decrease the environmental impact in each activity?
6. How does FLB Logistik AB balance the total cost in logistics activities and environment?
7. Whether FLB Logistik AB has reverse logistics. If it has, please describe the benefits and obstacles in reverse logistics.

The implementation of Environment Management System (EMS) in logistics systems
8. Whether FLB Logistik AB got ISO14000 Certification. If it has, what motivated FLB Logistik AB to get it? If not, which obstacles FLB Logistik AB has faced.
9. Whether FLB Logistik AB has EMS. If it has, how it is implemented in logistics system. And if not, which factors prevent FLB Logistik AB to use it.
Appendix 3

Questions sample About what Sandvik SMT asks their suppliers in the supplier evaluation tool:

Environmental part

1. Does the company apply any environment system (State which in comments)?
2. Has the organization identified the environmental influence of your operation (Describe shortly in comments)?
3. Are measurable environment goals defined by the company (State which in comments)?
4. Does the company educate the employees about the environmental influence of your operation?
5. Does the company perform measurements of fuel consumption continuously (Describe shortly in comments)?
6. Does the company continuously follow-up the average age of the vehicles/vessels?
7. Does the company continuously publish any environmental report (Describe shortly in comments)?
8. Are your sub suppliers evaluated regarding environment on a similar way as this evaluation of supplier?

Sample form for collecting the statistics from their suppliers on a quarterly basis:

<table>
<thead>
<tr>
<th></th>
<th>Domestic Sverige</th>
<th>Transported ton-km</th>
<th>CO2 (ton)</th>
<th>Nox (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO (kg)</td>
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<td>HC (kg)</td>
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<tr>
<td>Export from Sverige</td>
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<td>CO (kg)</td>
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<td>HC (kg)</td>
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<tr>
<th></th>
<th>PM (kg)</th>
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<tbody>
<tr>
<td>CO2 (ton)</td>
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<tr>
<td>Nox (kg)</td>
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