Maintenance impact on Production Profitability

- A Case Study

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Maintenance impact on Production Profitability - A Case Study

Sammanfattning/Abstract

Maintenance has had a tremendous impact on company’s proficiency to optimize its production system in order to meet its long term objectives. Generally, a production system in which maintenance is not given attention may easily lead to the system producing defective product as a result of machine defect.

The purpose of this thesis is to utilized tools and methods to analyze the impact of maintenance implementation in a production system. The analytical Hierarchy process was utilized to filter the defining factors and sub-factors considered to be related to the life length and performance of production equipment in the research which was carried out at SCA Packaging Sweden AB. Various cost associated with these factors were analyzed using the cost breakdown structure, an element of life cycle cost analysis. Finally, economic evaluation of the filtered factors was performed to show the benefits associated with implementing maintenance.

The result shows that while investment on maintenance implementation might be a cost at the earlier stage of implementation because it is hard to measure and follow up its impact on company’s business. Nevertheless, its role in improving company productivity profitability is indispensable. Thus, maintenance is a profit centre rather than a cost centre.

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- Anders Ingwald - Supporting supervisor
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- Joachim Nordberg - Operation Manager SCA Packaging Sweden AB

We would also like to thank our families for their prayer in making this work a reality and our friends (too numerous to mention) for their unprecedented support in different ways.

Obamwonyi Martyn Enofe _______________
Gregory Aimienrovbiye ________________

Linnaeus University
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Explanation of some terms

Efficiency
The ratio of the prescribed resources expected to be used, ideally, over the resources actually used. It measures how economically the firm’s resources are utilized when providing a given level of objectives, e.g. output requirements. (Alsyouf, 2006)

Level of maintenance
The set of maintenance actions to be carried out at specified indenture level. (BS 3811: 1993)

Maintenance
The combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function. (EN 13306: 2001)

Maintenance policy
A description of the interrelationship between the maintenance echelons, the indenture level and the level of maintenance to be applied for the maintenance on an item (BS 383811: 1993)

Maintenance Strategy
The management method used in order to achieve the maintenance objectives. (EN 133O6:2001)

Maintenance echelon
A position in an organization where specified levels of maintenance are to be carried out on an item. (BS 3811: 1993)

Productivity
Is the relationship between what comes out of an organizational system (assuming that the output meets the attributes established for them) divide by what comes into the system (i.e. labor, capital, material etc.) during a given period of time. (Alsyouf, 2004)
Performance
Is the level to which a goal is attained (Alsyouf, 2004)

Profitability
Is the best overall indicator of company performance; it measures the outcomes of all management decisions about sales and purchase prices, level of investment and production, and innovation, as well as reflecting the underlying efficiency with which input are converted into output. (Alsyouf, 2004)
### Table of abbreviation

<table>
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<th>Description</th>
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<tr>
<td>AHP</td>
<td>Analytical Hierarchy Process</td>
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<tr>
<td>CBM</td>
<td>Condition based Maintenance</td>
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<td>CBS</td>
<td>Breakdown Structure</td>
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<td>CR</td>
<td>Consistency Ratio</td>
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<td>CCI</td>
<td>Canadian Conservation Institute</td>
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<td>CM</td>
<td>Corrective Maintenance</td>
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<td>FMS</td>
<td>Flexible Manufacturing System</td>
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<td>JIT</td>
<td>Just In Time</td>
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<td>LCC</td>
<td>Life Cycle Cost</td>
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<td>LCCA</td>
<td>Life Cycle Cost Analysis</td>
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<td>PM</td>
<td>Preventive Maintenance</td>
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<td>SEK</td>
<td>Swedish Kronor</td>
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<td>TPM</td>
<td>Total Productive System</td>
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Abstract

Maintenance has had a tremendous impact on company’s proficiency to optimize its production system in order to meet its long term objectives. Generally, a production system in which maintenance is not given attention may easily lead to the system producing defective product as a result of machine defect.

The purpose of this thesis is to utilized tools and methods to analyze the impact of maintenance implementation in a production system. The analytical Hierarchy process was utilized to filter the defining factors and sub-factors considered to be related to the life length and performance of production equipment in the research which was carried out at SCA Packaging Sweden AB. Various cost associated with these factors were analyzed using the cost breakdown structure, an element of life cycle cost analysis. Finally, economic evaluation of the filtered factors was performed to show the benefits associated with implementing maintenance.

The result shows that while investment on maintenance implementation might be a cost at the earlier stage of implementation because it is hard to measure and follow up its impact on company’s business. Nevertheless, its role in improving company productivity profitability is indispensable. Thus, maintenance is a profit centre rather than a cost centre.
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1. Introduction

The introduction chapter begins with the background to the study, looking generally at maintenance as a support function in manufacturing/industrial environment and production capacity. Further, the problem discussion highlights and take into account the impact of maintenance in production processes of an organization. The problem discussion is thereafter narrowed down where the problem formulation and the research question will be presented. Some limitations with regard to this study are also stated.

1.1. Background

Industries in the 21st century are faced with challenging needs to optimize their production system due to the continual evolving world of technologies, global competitiveness, environmental and safety requirement, and the perception towards total quality with different aspects threatening company’s profitability. In addition, Manufacturing capabilities, customers and stakeholder expectation has lead to increased pressure for both variety of production and swiftness in production. Thus, product and process flexibility as a means to meet customer demands are vital for today’s companies to survive in business considering the competitive environment they operates (Vollmann et al. 2005; Davies, 1998).

With the increased use of automation and mechanization, such as Flexible Manufacturing System (FMS), Just-In-Time (JIT), robot systems in today’s industries, availability becomes a key issue in the manufacturing environment because possible breakdown is more likely to affect production and product quality. Hence, company’s capabilities to produce goods are associated with different challenges which include increased pressure for speed and variety in production, availability, quality, and efficiency (Alsyouf, 2004; Al-Najjar, 2007; Wireman, 1990).

In general, maintenance activities include fixing any kind equipment or component in a working order to prevent fault or error from arising, so as to perform its intended function, ensuring safety, as well as protecting the environment considering the fact that environmental management has turn out to be one of the principal issues companies are facing as a result of the effect it has on all aspect of the company’s operations (Al-Najjar et al. 2001; Henriques & Sadorsky, 1999).
Ensuring cost effective operation such as efficient production, machine availability, employee and environmental safety, as well as maintaining high quality production, generally depends on how organizations are able to effectively integrate maintenance with other working areas of the company. Hence, for companies to survive in the ever evolving industrial environment, machine/equipment ought to be ideally maintained in an operating condition and should perform its intended functions effectively (Ben-Daya & Duffuaa, 1995).

1.2. Problem discussion
Company’s ability to promptly and in greater varieties bring new product and services into the market is a key element of the operations management system in today’s organization, thus, maintaining availability of production equipment and ensuring production efficiency is essential to sustaining production capacity and fundamental factors affecting profitability. Studies have shown that the negligence of maintenance and its role in the production processes or company business often result in diverse consequential issues such as financial, technical, as well as safety in both internal and external environment of the organization (Bennett, 2006; Al-Najjar, 2001).

Maintenance is not just about ensuring proper function of machine and equipment (in order to continue to fulfill its intended purpose) but also play a key role in achieving company’s goals and objectives by improving productivity and profitability as well as overall performance efficiency. In generally, not until recently it role has been recognized, maintenance has been considered as a less important activity that only cost money rather than generating profit by most organization’s executives or stakeholders, due to the blurred perception about its role in attaining company’s goal and objectives (Duffua et al 2002).

1.3. Problem presentation
One fundamental motive for investing is the financial return on fixed asset, thus, asset management therefore emphasizes on achieving the lowest possible total cycle cost of producing the required quality product (Eti et al. 2006). According to Al-Najjar (2001) having an efficient maintenance policy in production system can help attain a trouble free operation throughout the production process to ensure that product are produce with the right quality, delivered at the right time and at a competitive price. Nevertheless, the dilemma company’s
executives and stakeholders often faced the inability to identify and quantify maintenance impact on company’s business because of the perception about maintenance being an unnecessary activity that only cost money with little or no return on the company’s investment. Thus, the profitability aspect of maintenance is blurred to most organizations (Al-Najjar, 2007).

1.4. Problem formulation

How can maintenance implementation in a production system improve production profitability?

1.5. Purpose

The objective of this thesis is to theoretically study and utilize tools and methods in showing maintenance impact on essential components of the production system in a view to improve production profitability. Therefore, the study focuses on the assessment of different factors and sub-factors influencing the performance of a production process (taking into account machine operational life length requirement, machine performance on company’s business and the environment) that impede production profitability.

1.6. Relevance

The impact of maintenance on business performance aspect such as productivity and profitability has increased indefinitely in recent times due to its role in ensuring and improving machine availability, performance efficiency, product quality and swift delivery, environmental and safety requirements. Thus, theoretically, this study is of relevance in the sense that it provides an insight on the significant role maintenance play in achieving business goals and objectives, and its relationship with productivity and profitability. Though maintenance impact on business objectives has been proven as important in recent time, much research would still be needed to add to the growing organizational perception of maintenance importance especially in manufacturing environment (Alsyouf, 2007).

Having an effective and efficient production system is one of the underlying factors in today’s manufacturing company. Hence, the process ensuring that the task of the study is covered
would provide the need for maintenance implementation is today’s production system to drive the perception towards ensuring production efficiency, production capacity and thus, production profitability.

1.7. Limitation

Considering the limited time assigned to this study, this thesis work will cover only the element of the production system. Knowing that maintenance is of low interest to the plant, some assumptions were made during the course of the economic evaluation of factors relating to the production system at the plant. The implementation process of maintenance at the case plant are not included in this study, however, relationship between maintenance and other main component of the production system will be highlighted.

1.8. Time frame

The time frame for the execution of this thesis work is as shown in table 1 below.

<table>
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<tr>
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<td>Literature survey</td>
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<td>Conclusion</td>
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<td>Presentation</td>
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*Table 1.1- Time frame*

The preliminary work of the thesis started on week eleven (11) with literature survey on scientific journals, articles, text books etc. with respect to the area of study, followed by the
commencement of the study paper, i.e. writing of the introduction chapter. The methodology chapter begins immediately, which was followed by the theoretical chapter, the empirical findings chapter and the analysis chapter. The result and conclusion chapter follows afterwards and finally handing in of the complete paper.

1.9. Thesis disposition

This study is discerned in the parts of Introduction, Methodology, Theoretical framework, and the Empirical findings. This is followed by the Analysis, Results and Conclusions which is a normal in writing a thesis. Figure 1.1 below describes the disposition of this thesis.

Fig 1.1 – Thesis disposition
2. Methodology

This chapter aims at highlighting the different approaches that can be utilized when conducting a study. It specifically addresses the research strategy, scientific paradigms, research method and data collection method. It further highlights the methods used in conducting this study and their relevance to the study.

2.1. Research strategy – Case study

A case study as explained by Yin (2003) is but one of several ways through which the science of social research can be carried out. He further stated that other ways through which social science research can be conducted includes experiments, survey, histories and archive record analysis. A case study research can be said to comprise of both multiple and single case study, and can be based on a mixture of both qualitative and quantitative evidence but not to be confused for qualitative research. Generally, case studies are the preferred strategy where question of “how” and “why” are being posed, and when the researcher does not have much control over the event or object of study, as well as when the focus is on a contemporary phenomenon within some real-life context. Such explanatory case studies according to Yin (2003) can also be complemented by two other types which are the exploratory (a study indicating how certain events are explained) and descriptive (a study conducted as a result of a problem that is not clearly defined) case studies.

2.2. Scientific paradigms

Positivistic and hermeneutic perspectives are considered to be the two main scientific paradigms when conducting a research. Positivism is said to have originated from natural science, while hermeneutics has its origin in human science. The positivistic perspective is considered to be the correct scientific paradigm; positivistic foundation relies exclusively on numerical analysis of data collected through ways of relating and comparing studies and experiment (Gummersson 2000). According to Patel et al. (2003) positivist attempt to absolute knowledge and believe that their perspective should be more of the spectator in order not to have a bias judgment of the research object or their observation should not to be influenced by their religious or political view.
On the other hand, hermeneutics perspective rejects the science ideal of research, instead it is founded upon interpretation and understanding of meanings as there are differences in natural science with regards to people and the object under study (Patel et al. 2003). The hermeneutics researcher craves for the holistic view of the research problem and believes more in personal interpretive process towards understanding, thus, researchers in this tradition are allowed to be subjective and devoted. Pre-understanding in the hermeneutic perspective is considered as a requirement as this will help the researcher to understand and interpret conditions (Patel et al. 2003).

**Pre-understanding**

Pre-understanding is an essential concept in the hermeneutic approach. Pre-understanding is an indispensable prerequisite for an individual to understand something because it gives direction to a research. Thus, reality is not perceived only by our five senses, but interpreted in our brains through the help of our earlier knowledge, i.e. pre-understanding. Hermeneutics theory shows that interpretation and understanding of situation can be fashioned by studying the human nature, action and language (Bryman & Bell 2007; Patel et al. 2003).

### 2.3. Research approach

There are different types of research approaches a researchers can make use of when relating theories with empirical “real world” data. The commonly used research approach however is the deductive, inductive and abductive approach. The deductive approach starts from existing theories that has been developed in that particular field, and are used to test the hypothesis and the formulated research question. Based on the hypothesis and research questions, the empirical data is gathered thereafter comparison is made on the theories and the empirical data so as to arrive at a conclusion analytically (Gummersson 2000; Bryman & Bell 2007).

The inductive approach on the other hand is based empirical facts; it starts with empirical data gathering where the researcher develops a concept that is then used to structure the theories. A distinct characteristic between the two mentioned approaches is that where deductive principally tests already existing theories, the inductive approach generates new theories (Gummersson 2000).
The abductive approach is a continual interaction between the theoretical framework, empirical fieldwork and the case analysis, leading to the development of new theories. The researcher in this regards initiates a creative iterative process of “theory matching” or “systematic combining” in an attempt to finding a possible matching framework or extent the theory that has been used prior to this observation (Spens and Kovács, 2006).

The first step to abductive approach is inductively preparing the theory through which the case study is then clarified and explained. Next step is testing the newly prepared theory on the case study. This kind of method demands experience about the area of apprehension and also on similar cases, thus, cannot be used schematically (Saunder et al. 2007).

2.4. Data collection method

Data collection according to Yin (2002) is the first step taken when planning and implementing a case study because when collected data is incomplete, the researcher is often face with difficulties in analyzing the data, which can lead to a the quality of the intended research been poor.
The author proposed six different techniques through which data are collected for a case study type of research, i.e. interview, direct observation, documentation, participant-observation archival records and physical artifact. Yin (2003) suggested the use of interview methods which is considered as one of the most important source of data/information gathering in a case study. Conducting a case study interview according to Yin (2003) entails maintaining simultaneously two distinct levels by the interviewer, i.e. satisfying the purpose of the interview, and asking questions that is not posing any form of inconveniences in any way whatsoever to the respondent at the same time.

There are two main methods for collecting data according to Bryman & Bell (2007) includes the qualitative and quantitative methods. Qualitative method strives to associate group or individuals meaning to societal issue through means of exploring and understanding. The focus in qualitative research method in a process of collecting and analyzing data is more on words (Creswell 2009; Bryman & Bell 2007).

In contrast, the quantitative method kind of data is numerical in nature. The quantitative research method, the relationship between variables can be measured which is characteristically on instrument, thus numbered data are analyzed with the use of statistical procedures (Creswell 2009). The difference between these two according to Ghauri & Gronhaug (2005) depends on the overall form and the emphasis, and objectives of the nature of the study.

2.5. Result evaluation

Validity, reliability and generalization of result are sets of logical test that can be used in judging the quality of the result of a research. Criteria like data dependability, consistency and sincerity are mainly used in making the judgments. Victor (2006) enumerate that researches are evaluated against the above mentioned criteria so as to address the intended audience for the study.

2.5.1. Validity

Validity measures the degree to which the result of a study can be generalized. It is the extent to which a variable accurately enumerates the theoretical concept it was intended to measure
Victor (2006). The validity of both the method and design of a research should be checked according to Henrichsen et al. (1997), as an indication of how good a research is pre-arranged. Thus, in order to ensure research legitimacy, potential factors that might be a hindrance to the validity of the research should be given a close concern. There are several categories of validity, two of them are internal validity and external validity, and are described below.

**Internal validity** – It shows whether or not the result of a study is in accordance with reality. Yin (2002) institutes a fundamental connection between the conditions where certain conditions are shown to lead to other condition, i.e. if the outcome of event \( x \) can lead or affect even \( y \). In the same vein, the author reiterates that internal validity in case study may be extended to a broader issue of making conclusion. Internal validity may well also measure the extents whereby researchers can assume that casual relationship exist between two or more conditions (Ghauri & Gronhaug, 2005).

**External validity** – It deals with the issue of initiating a platform on whether the research findings from a particular study can be generalized beyond the immediate case study. It should be noted however that generalization may be somewhat impossible to the required extent and depth (Yin 2002).

2.5.2. **Reliability**

It refers to the stability or legitimacy in result, and the tendency of a measurement to produce the same result when the same entity is measured over again by another person (Grinnel & Williams 1990). In Yin (2003) opinion, the objective is to be sure that if a different researcher applies the same procedures that has been previously used or described in a case study, the finding and conclusion obtained should be the same as the previous one. The goal of reliability according to Yin (2003) is to minimize any forms of error and biases in a case study. Thus, approaching problems associated with reliability entails developing many steps as operational as possible and conduct the research in such a way that the researcher feels there is no space for error or blunder.
2.5.3. Generalization of result

In the opinion of Saunders et al. (2007) generalization sometime interrelate to external validity where hypothesis, result and conclusion can be generalized. The difference between them is that external validity is related with analysis and explanation of the application of hypothesis to similar event, while generalization on the other hand is related with the usefulness of hypothesis beyond its limitation. Generalization according to Bloor and Wood (2006) is the degree, to which the result of a research study can be applicable to other settings, thus, making a wider applicable proposition. A generalized research is one whose result and inference is capable of being use generally.

2.6. Thesis research method

In writing this thesis, scientific and research approaches were utilized in order to perform a comprehensive report according to report template used in the department of Terotechnology (systemekonomi) for report writing.

This thesis will adopt the case study method because this study will be dealing with both descriptive and explorative approach. The descriptive side of the study will look into the object of study (production system); evaluation of the effect of losses associated with the study object due to maintenance, thus, highlighting the importance of maintenance implementation. The exploratory approach will look at ways through which maintenance can be implemented in the study object. We then believe that this method is best for this study because as a researchers, we have little or no influence over the object of study, thus as proposed by Yin (2003).

This thesis will also consider the perspective of positivistic paradigm, which means the nature of the study will be mainly objective. However, the study will also consider hermeneutics paradigm because the research is also going to be influence by personal values and interpretation, thus, subjective evaluation maybe be involved too.

Furthermore abductive research approach will be used (which combines both inductive and deductive approaches) because the main requirement of this study is developing an existing
theories. Previous knowledge in maintenance study will be iterated with observation from the company which can be considered as theory matching.

Both qualitative and quantitative method will be basically used to gather data from the case company through interviews/questionnaire to key personnel at the case company, observation and archival documents. While the theoretical framework will be structured through literature survey, scientific journals, articles and books relevant to this study.

In this thesis, validity and reliability will be used to test the quality of this thesis, the discussion and analysis of the gathered data will be carried out carefully with key personnel at the case company. Thus, our conclusion will be base on the outcome of the gathered data from the case company (i.e. an event X would lead to event Y) referring to Yin (2003) in the previous section of this chapter, therefore increasing the reliability of the thesis. Also, this thesis pre-understanding of is based on experience during the course of study at the department of Terotechnology (Systemekonomi) as well as the five senses.

### 2.7. Summary

The chosen methodology decisions which enclose the methods and techniques employed in designing this thesis is summarized below. This is in view to give the reader a clear overview of the methods used.

<table>
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<th>Research Strategy</th>
<th>Scientific paradigm</th>
<th>Scientific approach</th>
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<td>* Case study</td>
<td>* Mainly Positivistic</td>
<td>* Abductive</td>
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<td></td>
<td>* Hermeneutics</td>
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<th>Research approach</th>
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<td>* Qualitative</td>
<td>* Primary</td>
<td>* Single case study</td>
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<td>* Quantitative (data)</td>
<td>* Secondary</td>
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*Fig. 2.2 – Summary of methodology used*
3. Theoretical Framework

The necessary theories that are relevant for this study are presented in this chapter. It starts with describing Maintenance and its impact; followed by the relationship between Maintenance and Production; Maintenance and Quality; Maintenance and profitability. Also described in this chapter is the Maintenance Organization; Life Cycle Cost Analysis; Maintenance cost; the Analytical Hierarchy Process; as well as the Maintenance Function Deployment and Quality Function Deployment. This is in view to increase the reader’s understanding of the study.

3.1. Maintenance and its impact

Maintenance is defined according to the European standard (EN 13306: 2001) as “the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function”. Also in the same vein, Blanchard (2004) defined maintenance as all required and essential actions which are needed for keeping a system/ product within its life cycle in a functional and operative and condition, or restoring it to a state it can performed the intended function. Maintenance action according to the author entails some sets of important inputs e.g. manpower (labor), tools, equipment, management, spare parts and information.

According to Al-Najjar and Alsyouf (2004) the significance of maintenance function has over the years increased due to its role and impact on other working areas (e.g. production, quality, etc.) in an organization, i.e. improving machine availability and product quality. Efficient maintenance contributes by adding value through better utilization of resources (i.e. higher output), enhancing product quality as well as reducing rework and scrap (i.e. lower input of production cost) (Alsyouf, 2004). In addition, the increasing awareness of maintenance and its influences on both industrial and the society at large according to Alsyouf (2006) can be recognized.

Many researchers and practitioner have emphasized on the total losses caused by maintenance omission or ineffectiveness in maintenance. Nonetheless, maintenance is still considered as a cost centre based on the survey conducted on 118 Swedish manufacturing companies where 70 percent of the respondents consider maintenance as a cost centre.
Maintenance is classified into two major areas, i.e. Preventive maintenance – all planned maintenance actions e.g. periodic inspection, condition monitoring etc. while Corrective maintenance includes all unplanned maintenance actions to restore failure (Blanchard, 2004). Figure 1 below shows the maintenance overview according to EN 13306: 2001

![Maintenance Classification](image)

**3.2. Maintenance and production**

Al-Najjar (2007), affirm that the main task of production is to produce goods/products. Nevertheless, efficient maintenance policy influences production capacity of machine used for producing these products. Maintenance therefore can be considered as an organizational function that functions in parallel with production. While reiterating that production produce product, the authors also express that maintenance produces the capacity for production. Thus, it can be said that maintenance affects production by increasing production capacity while also controlling the output quantity and quality (Ben-Daya & Duffuaa, 1995).

In the same vein, Ben-Daya & Duffuaa (1995) lamented that though maintenance role in accomplishing production objectives has already been pointed out in literatures, much remain to be done in order to integrate maintenance and production because in most models, maintenance is viewed as a limiting constraint and the question is how to meet the production
master schedule under maintenance constraint. Thus, the integration of maintenance and production has to be based on a clear understanding of their relationship.

3.3. Maintenance and quality

The role of maintenance in long-term profitability of an organization has long been known, leading to researcher and practitioner to develop maintenance strategies that contribute to long-term company’s profitability. Company’s survival and profitability however cannot be achieved without sustained product quality. Quality according to the authors has been recognized as the main edge for competitiveness and long-term profitability in modern day global economy. Thus, maintenance role in this endeavor cannot be overemphasized (Ben-Daya & Duffuaa, 1995).

The author’s further affirm that though the link between maintenance and quality has been identified by Total Productive Maintenance (TPM), there seems to be no adequate model relating quality and maintenance. In general however, the authors emphasize that machines/equipments which lack maintenance and fail periodically experiences speed losses or lack precision, and hence tend to produce defects. Such equipment often drives production processes out of control. Thus, a process that is out of control is bound to produce defected products, and at the same time increasing production cost which amounts to less profitability, thereby putting organizational survival at risk. This statement, demonstrates a strong link between equipment maintenance and product quality (Ben-Daya & Duffuaa, 1995).

3.4. Maintenance and profitability

Profitability according to APQC cited in Alsyouf (2004) is the product of productivity and price recovery. Hence, productivity is a function of the production process efficiency and effectiveness. The author however reiterates that when evaluating maintenance profitability, the impact on other working areas is also measured (e.g. by affirming maintenance role in machine life cycle profit). Maintenance improvements in general aim at reducing cost of operation and improving product quality, thus, the cost effectiveness of each improvement action may well be scrutinized through evaluating the relevant cost constraint before and after improvements (Al-Najjar 1997 cited in Alsyouf 2004).
Low cost and differentiation according to Porter (1985) cited in Kans (2008) are two generic ways a company can react with regard to the external environment so as to achieve competitive advantages. Product low cost can be attained by uptight cost control, economies of scale or minimization of cost that is associated with support activities. Differentiation on the other hand aims at offering something the customers perceived as unique as shown in figure 3.2 below.

![Diagram of maintenance and profitability connections](image)

**Fig 3.2 – Connection between maintenance and profitability (Kans, 2008)**

### 3.5. Maintenance organization

Maintenance organization according to Kelly (1984) consists of three essential and interconnected components, i.e. Resources, administration and work planning and control system.

- **Resources** – includes personnel, tools/equipments, spare parts, composition etc.
- **Administration** – hierarchy of authority and responsibility for deciding what, how and when work should be done.
• **Work planning and control system** – mechanism for planning and scheduling work and feedback information needed if maintenance effect is to be properly directed towards its defined objectives.

Kelly (1984) further express that in most cases the problem often faced with maintenance organization is achieving the optimum balance between plant availability and maintenance resources utilization. Maintenance organization may take an infinite number of forms, leading to the best been determined by systematic consideration of factors like maintenance workload, unavailability cost, plant location, amount of emergency work, production organization and maintenance resources.

3.5.1. Objectives of maintenance organization

The objective of a maintenance organization lies in the ability to match maintenance resources to the maintenance workload aiming at the task of achieving and sustaining optimum availability (Wireman 1990). According to Kelly (1984) maintenance organization need continuous modification so as to respond to the changing requirements of maintenance and production system being because of its continuous evolving nature. A maintenance organization characteristic includes;

• Maximizing production and ensuring equipment availability at a lower cost with higher quality.
• Optimizing available maintenance resources
• Gathering of necessary costs information associated with maintenance (e.g. labor cost, material cost, tool/ equipment cost etc)
• Employing ways of decreasing expenses associated with maintenance and operation by identifying and implementing cost reduction.

3.6. Life Cycle Cost Analysis (LCCA)

Life cycle cost (LCC) according to Berliner and Brimson (1988) is “the total cost of all the activities that occurs within the whole life cycle of a product or service”. LCC involves the optimizing value for money of physical assets, taking into account all cost factors associated with the asset during its life length or operating life (Hart, 1978; Hysom, 1979).
The total life cycle costs include all the costs related to design and development (CD+D), production and construction (CP+C), operation and maintenance (CO+M), and disposal and support (CD+S). See equation below;

\[
\text{LCC} = CD+D + CP+C + CO+M + CD+S.
\]

Each cost category of LCC as described by Blanchard (2004) is as follow;
- **CD+D**: costs of the research, system analysis, detail design and development, fabrication assembly, and associated document evaluation cost.
- **CP+C**: cost of investment in production facilities, machines, tools and equipments, training and operational system test.
- **CO+M**: cost of machine operation and maintenance, personnel training, maintenance support activities, spare, machine/ equipments, transportation, as well as modification.
- **CD+S**: cost of the disposal or scrapping of the machines/ equipments.

According to Davis et al. (2003) life Cycle Cost Analysis techniques aims at the inclusion of all relevant cost that are associated with a product in order to attain a systematic and balance view of cost versus benefits. The total cost is then achieved by summing the costs associated with the life cycle phases. The authors further expressed that each phase of the life cycle cost may be broken down further into more specific areas which is referred to as **Cost Breakdown Structure (CBS)**. The Cost Breakdown Structure is a hierarchical structure that initially breaks down the LCC into design and development, production and construction, operation and maintenance and finally disposal. The resulting figure of tree like structure and the branches within the structure then act as a placeholder that attaches cost and benefits of the total life cycle cost (Davis et al. 2003).

### 3.7. Depreciation

The term depreciation is an accounting concept which creates a yearly deduction against before-tax income in a way that the effect of passage of time and usage on the asset value reflects in organizational financial statements. Depreciation can be defined as a systematic and rational system of distributing the cost associated with tangible assets throughout the life span. When calculating for depreciation, different methods are used. But the commonly used
ones are the straight line depreciation method, declining balance depreciation method and the sum-of-the-year digits method (Sullivan et al. 2006).

- **Straight line depreciation**
  This method presumes that the depreciation of an asset through the passage of time and usage is constant over the years. It is often viewed as the simplest among the depreciation methods because it distributes an equal amount of depreciation to each account (Andrew et al. 2006). It is computed as follows;
  
  \[
  \text{Annual depreciation} = \frac{(\text{cost} – \text{salvage value at each year end})}{\text{asset life span}}
  \]

- **Declining balance depreciation**
  This method assumes that the yearly cost of depreciation is a fixed percentage of the net book value in the start of the year. It is computed by;
  
  \[
  \text{Annual depreciation} = (\text{net book value at the beginning of the year} \times \text{depreciation rate}, R)
  \]

  \[
  \text{Where } R = \frac{2}{N}, \text{ when } 200\% \text{ declining balance is employed}
  \]

- **Sum-of-the-digit method**
  This method entails that a fraction is calculated yearly before it is multiplied by the depreciable sum/cost. The years that is left to be depreciated is the numerator, why the sum/cost of the year digits of the depreciable asset life. It is computed by;
  
  \[
  \frac{N (N+1)}{2}, \text{ Where } N = \text{depreciable asset life} \text{ (www.allbusiness.com, assessed 24th May 2010)}
  \]

3.8. Maintenance cost

Maintenance cost or maintenance related costs in general are usually divided into direct and indirect cost without putting maintenance savings and profit into consideration (Al-Najjar and Alsyouf, 2004). Direct and indirect costs according to Waeyenbergh and Pintelon (2002) include cost that are connected with in-house and out-house (outsourcing) maintenance activities. Al-Najjar and Alsyouf (2004) further refer to direct maintenance costs as costs associated directly to the maintenance activities, which include the internal costs that are required to carry out the maintenance functions e.g. labor, tools, spare parts, training etc. and other maintenance expenses that are directly related.
Indirect costs on the other hand includes all costs that are indirectly related or associated with maintenance, which can be attributed to issues like profit loss due to production losses during planned and unplanned stoppages, customer losses, reputation and consequently loss of market share as a result of maintenance related factors. In addition, indirect maintenance costs includes performance inefficiency costs due to short stoppages and reduced speed, poor quality cost due to maintenance deficiency, idle fixed cost resources e.g. idle machine and idle worker costs during breakdowns, delivery delays penalty cost as a result of unplanned down time, assurance claim from dissatisfied customers as a result of maintenance related poor quality (Al-Najjar and Alsyouf 2004).

3.9. Decision making / Analysis tools

According to Bhushan et al. (2004) there is need for rational approach to problem with extremely high stakes, where human perceptions and judgments are involved, and whose solution might have a long-term impact. Various multi-criteria decision making model or techniques (e.g. Analytic Network Process (ANP), Analytic Hierarchy Process (AHP), etc.) are use for decision making at strategic level. However, with respect to this study, AHP was chosen because of its ability in breaking complex situation into part and compare them (pair-wisely) over each other, and also derives numerical weight or priorities for each of the elements which allow the elements to be compared with each other in a logical and reliable way. This is the fundamental capabilities that differentiate the AHP from other decision making techniques/methods.

3.9.1. Analytic Hierarchy Process (AHP)

The AHP is a multiple criteria decision-making technique which was developed by Thomas Saaty in the 1970s, which have been used in a broad range of decision situation worldwide. For example, it has been used in the field of government, industries, business, education etc. the concept is based on the intrinsic human ability to make suitable judgments about small problem. It involves pair-wise comparison process, whereby the overall hierarchy of the decision is laid out. The factors and various alternatives to be considered in the decision are reveal in the hierarchy, where a number of pair-wise comparisons is then made, resulting in determining the weights and evaluations of the factors (Bayazit 2005).
Labib et al. (1998) describes AHP as a method that derives ratio scales from reciprocal comparisons, involving breaking down complex situation into its constituent parts, arranging these broken parts into a hierarchical order, assigning numerical values to subjective judgments on the relative importance of each. These judgments are converted mathematically by an AHP software into priorities for which is assigned to each factor in order to show how consistent the judgments are. This software have been designed and used by the Canadian Conservation Institute (CCI) to assist in the assessment and prioritization of relative importance diverse criteria when deciding on the most suitable option (www.cci-ice.gc.ca/tools/ahp/index_e.asp). The consistency of the judgments is express with the consistency ratio (CR) which is the comparison between the index and random consistency index. The value of the consistency ratio in absolute mode is equal to 0.1 otherwise the judgments are rendered untrustworthy (Labib et al. 1998).

Bayazit (2005) proposed three steps of AHP methodology, i.e.

Step 1: Structuring the hierarchy – grouping and arranging related component into a hierarchical order that reflects functional reliance of one/ group of components on another.

Step 2: Performing aired comparisons between element/ decision alternatives – constructing a pair wise matrix comparisons of elements where the entries indicates the strength with which one element dominates another using a method for scaling of weight of the elements in each of the hierarchy levels with respect to an element of the nest higher level.

Step 3: Synthesizing result – priorities are synthesize to obtain each alternatives overall priority, whereby the alternative with the highest priority is selected.

3.10. Theoretical approach of the study

The theoretical approach/ framework of this thesis are described below. It entails the process or approach to this study with respect to the main aspects considered as significant to the scope of the study. The first step of the framework begins with the assessment of different aspect in the plant directly related to maintenance, production equipment and processes leading to production profitability.

The three defining aspects that were considered (with respect to production equipments) were the machine/ equipment operational life length, machine impact on the surrounding
environment (both internal and external) and the machine impact on the company’s business (see figure 3.3).

Aspects related to production efficiency and profitability
(E.g. machine degradation, production capacity, product quality, environmental & employee safety etc.)

The next step is the assessment of the different factors affecting the mentioned aspects (i.e. machine operational life length, machine impact on the surrounding environment and the machine impact on the company’s business) considering that there are several factors associated with the three aspects. Furthermore, the sub-factors that are influential to the
factors associated with the three mentioned aspects are evaluated in order to filter-out the significant sub-factors relating to these aspects.

Finally, the filtered sub-factors are presented and analyzed to see the economic benefits and losses of these sub-factors in relation with production profitability.
4. Empirical Findings

This chapter gives an overview of the case company, SCA Packaging, its business areas, brief history of the SCA Packaging in Sweden, the production process and product produce in the Urshult factory, gathered during our visit and also from the company’s webpage.

4.1. SCA Packaging overview

SCA Packaging is a leading provider of customer-specific packaging with emphasis on the state-of-the-art design and local service close to customer facilities. A member of the SCA global consumer goods and paper company that develops, produces and market personal care product, tissue, packaging solutions, publication papers and solid-wood products in more than 90 countries. SCA Packaging is Europe’s second largest producer of container board paper used for the manufacturing of corrugated board, creates value through knowledge of consumer and customers needs, regional presence and efficient production.

4.2. SCA’s businesses and market

The company’s business area consists of four different areas which includes Personal care, Forest products, Tissue, and Packaging.

**Personal care** - This consists of three product segments in the business area, i.e. incontinence care, baby diapers and feminine care. Production of these products is conducted at 23 facilities in 20 different countries, and the products are sold in more than 100 countries worldwide.

**Forest products** - Production of this products consist of publication papers, pulp and solid-wood products, which is conducted at 12 facilities in 3 countries. The forest products are mainly sold in Europe, also in Japan and North America.

**Tissue** - This consists of toilet paper, kitchen rolls, facial tissue, handkerchief and napkins. The company delivers complete hygiene concepts to companies and institutions in the Away-From-Home (AFH) tissue segment. The products are sold in some 80 countries and the production is conducted at 36 facilities in 18 countries worldwide.

**Packaging** - SCA supplies full-service packaging solution and offers both transport and consumer packaging. The production of the packaging product is conducted at about 200 facilities in 28 countries and sold in some 50 countries in Europe and Asia.
4.3. History of SCA Packaging in Sweden

SCA Group was officially founded in Sweden in 1929 through a merger of some ten Swedish forest companies into a single group comprising of forest, sawmills, pulp mills, machine shop and power companies. SCA had annual sales of approximately 100 million SEK, and production was carried out in some 40 Swedish units with 6,500 employees. SCA Packaging Sweden AB headquarters is located in Stockholm, Sweden. In 1971, a new EPS factory was built in Värnamo, Sweden.

4.4. SCA factory in Urshult (Division Cellplast)

SCA factory at Urshult presently has a total of 24 workers or employees with a total production of 12 tons per week. In December 2006, the factory was burned down and was rebuilt in 2008, with production starting also at the end of the same year. In 2009, the production material volume was 787 tons and the budget volume for the plant in Urshult for the year 2010 is 974 tons. The main customers are Electrolux, Nibe, and Automobile companies.

Among products that are produced at the factory includes packaging boxes and insulation material used for concrete buildings, which are made from Expandable Polystyrene (EPS). The packaging boxes and insulation materials used for concrete buildings are the two most important products at the factory due to the historical sales data and demands associated with the product (see figure 4.1).

![Fig 4.1 - Packaging boxes and insulation materials](image-url)
4.5. Organizational structure

The organization structure is a hierarchical structure with the head of division overseeing every department and operations. The organizational structure is presented below (figure 4.2).

![Diagram of SCA Packaging Division Organization](image)

Fig.4.2- SCA Packaging Division Organization

4.6. Production organization Structure

Presently, there are 15 machines, 3 production teams, 3 shifts at Urshult factory, the production teams comprises of 5 or 6 workers with 8 hours working time. The company uses prognosis for its production plan (which is also related to the annual budget) to decide the need for machine capacity.

Production outcomes at the plant are monitored twice a day to be able to see deviation from the production plan. The company uses make-to-order manufacture process through which orders are accepted from customers with a lead-time for 3 weeks (as a standard) however, some deviations do exist. For the next 3 weeks, orders are planned/ scheduled and checked.
against machine capacity. Customer’s orders are rescheduled based on the report made by the production teams and actual capacity, human workforce is then taken into consideration where extra workforce is added if needed, which is normally done in high seasons. The production organization combines both Värnamo and Urshult factory production structure as shown below (figure 4.3).

![Production Organization Diagram](image)

**Fig. 4.3 - Production Organization**

### 4.7. Production process overview

Production at SCA Packaging Urshult includes all the activities performed in producing a single product. The production is mainly based on customers order, and the production line comprises of different machines in a 3 machine lines for the production of EPS (Expandable polystyrene) as illustrated in the diagram below (figure 4.4).

The production process begins in the **Octabans**, where the raw materials (known as beads) are stored before it is been transported to the **Pre-expander** for heating. The Pre-expander heats and expand the EPS which is refers to as beads (see picture in appendix 1) to the required size before it is been transported to the **Silos** (see picture in appendix 2) were it is
stored for about 11 – 48 hours before it is been transported to different machine lines for the production of different sizes and shapes of the end product (see figure 4.4). The EPS production process flow is shown in appendix 3.

Fig 4.4 – SCA Packaging production process

The process is an automated process which requires optimum availability to ensure smooth operation or avoid bottleneck. The most critical machine in the process in the pre-expander because its function is to expand the EPS so it can be ready to use for production. If there is breakdown in the Pre-expander, there will be stoppage in production which when transferred into money (especially in peak season where demands are high) the company losses a lot as a result of production stoppage. Though the company does perform some maintenance work which the company refers to as simple maintenance, it is not enough for such company with automated and complex machines. The issue of downtime is aggravating and the management is hoping to do something about it in order to minimize or preferable eliminate such problem.

In addition to this, the steam machine is also a significant component in the production of EPS. Although the boiler that produces the steam is not included in the production process
diagram above, however, steam is very important in the production of EPS because the steam enables the EPS to expand during production. Breakdown also to the steam machine will automatically affect the production process resulting to unwanted stoppages.

4.8. Maintenance strategy/ policy
The factory at Urshult has a strategy of ensuring that production machines and equipments are ready for operations, which is regarded as preventive maintenance (i.e. changing of oil and oil filters, valves and preparation of production tools etc. However, the company does outsource some maintenance work (e.g. hydraulics) to their vendor in Germany.

On the other hand, the maintenance policy (i.e. the maintenance echelon, techniques and the level of maintenance) of the company is not in the right standard. Two personnel are presently assigned to maintenance work at the plant, and these personnel are also responsible for the preparation of tools used for production. The machine at the factory has economic life length of 10 years before it is been disposed.

4.9. Empirical framework
The empirical framework describes related factors (within the case company) associated with the chosen aspect presented in section 3.10 and figure 3.5 (Theoretical approach framework) in the previous chapter. A meeting and brainstorming session with the production and operation managers made it possible in determining the factors affecting the chosen aspects with respect to production profitability. Three factors (i.e. machine life length related, machine performance related and environmental related) were identified to be affecting the mentioned aspects (See figure 4.5).

With respect to the three identified factors associated with production equipment and process, two of the factors (machine life length related, machine performance related) were considered as the main factors affecting production profitability at the plant. Factors relating to the environment as shown in figure 4.5 was considered less important by the company’s respondents, thus, will not be evaluated in this study. Other sub-factors affecting the considered factors were highlighted by the production and operation managers as there are several sub-factors associated with the mentioned factors (See section 4.8 and 4.9)
Critical factors affecting production with respect to machine life length and machine performance

Assessment of different factors affecting the above mentioned aspects (e.g. maintenance & operation cost, product quality, production speed etc.)

Machine life length related
* Maintenance & Operation cost
* Disposal cost
* Transportation & Installation cost
* Utilities cost
* Depreciation cost

Machine performance related
* Product Quality
* Material usage
* Machine stoppages
* Speed delays
* Competence
* Loss production
* Overtime etc.

Environmental related
* Environmental protection cost
* Defective product disposal cost
* Water clean-up cost
* Workers insurance
* Air cleaning cost

Filtering influential sub-factors

Assessment of economic benefits and losses of filtered sub-factors

Critical factors affecting production with respect to machine life length and machine performance

Influencing sub-factors with respect to above mentioned factors

Fig 4.5 - Empirical framework

4.9.1. Machine/ equipment life length

As earlier mentioned, machine life length is one major factor that affects production profitability in the plant, as pointed-out by the production and operation mangers. The
influential sub-factors affecting machine life length with respect to the company’s profitability includes;

- Maintenance and Operations
- Disposal cost
- Transport and installation
- Utilities cost
- Depreciation cost

4.9.2. Performance of machine/ equipment

The performance of the production equipment was another important factor identified by the production and operation managers to have an effect on production profitability. Some sub-factors were also identified in relation with the equipment performance, these sub-factors includes;

- Product Quality
- Material Usage
- Machine Stoppages
- Speed Delays
- Competence

The third aspect which is the environmental (internal and external) related issues like environmental tax, defective product disposal cost, water clean-up cost, insurance for the workers etc. was another aspect at the company, nevertheless, as mentioned before, the percentage of impact (on the company’s profit) is low and was not directly related to the machine or production system.
5. Analysis

This chapter presents the main analysis of this study with respect to the problem formulation. Hence, the presented theories are used in relation with the empirical finding to analyze the current situation at the plant.

5.1. Analytical framework (Factors affecting production profitability)

The fundamental reason of company’s investment is to make profit, which can be affected by some significant factors. The aim at SCA Packaging (Urshult plant) today is to continue to improve return on investment (ROI) while also ensuring customer satisfaction. During a meeting session with the production and operation managers on the issue of production efficiency and profitability, the operational life length and performance of the machine were two fundamental factors directly linked with the production capacity and profitability. Consequently, other numerous sub-factors are associated with the considered factors (i.e. machine life length related and machine performance related) as shown in figure 5.1 below.

As mentioned before, there are numerous sub-factors or element associated with the considered factors, the sub-factors needs further assessment in order to bring out the most critical or influencing sub-factors relating to the machine life length and machine performance. Thus, the Analytic Hierarchy Process (AHP) was utilized (because of its ability to consider numerous alternatives and provides the suitable solution option in complex decisions making) to assess the sub-factors affecting the life length and performance of the machine so as to see the criteria with the highest priorities (see figure 5.1). The pair-wise assessment section of the mentioned factors and sub-factors associated with the machine life length and performance was carried out together with the production and operation managers and was paired accordingly using the scale of pair-wise comparison in appendix 4. The paired criteria was weighted and calculated in AHP software to the consistency ratio in order to express the consistency of weighted elements.

Lastly on the analytical framework (see figure 5.1) the criteria or sub-factors with the highest priorities relating to the considered factors is assessed with the life cycle cost& benefits analysis to show the economic benefit and losses with the implementing maintenance.
Aspects related to production efficiency and profitability (e.g. machine degradation, production capacity, product quality, environmental & employee safety, etc.)

Assessment of different factors affecting the above mentioned aspects (e.g. maintenance & operation cost, product quality, production speed etc.)

Filtering influential sub-factors

Assessment of economic benefits and losses of filtered sub-factors

Critical factors affecting production with respect to machine life length and machine performance

Influencing sub-factors with respect to above mentioned factors

The impact of maintenance on production profitability

Analytical Hierarchy Process (AHP)

Economic evaluation by adopting some concept of Life Cycle Cost (LCC)

Machine performance Impact on company business

Machine operational life length requirement

Impact of machine on surrounding environment, safety, etc.

Machine life length related

* Maintenance & Operation cost
* Disposal cost
* Transportation & Installation cost
* Utilities cost
* Depreciation cost

Machine performance related

* Product Quality
* Material usage
* Machine stoppages
* Speed delays
* Competence

Aspects related to production efficiency and profitability (e.g. machine degradation, production capacity, product quality, environmental & employee safety, etc.)

Fig. 5.1. – Analytical framework
5.2. Machine life length

From the analysis framework (figure 5.1) the life length of the machines is a fundamental factor affecting production profitability in the plant considering the period it is proposed or expected to run before it is being disposed. The machine life length is characterized by costs associated with running the machine, like maintenance and operation cost, disposal cost, transportation and installation cost, utilities cost and depreciation cost as shown in figure 5.2 below.

![Machine life length](image)

**Fig.5.2. – Major factors affecting machine life length**

Assessment of the machine life length was analyzed by the element of the life cycle cost of a machine (i.e. the total cost associated with the projected functional life span of the machine, from design and development, production, operation, maintenance, support and disposal) of the machine. The assessment was carried out though a session of brainstorming with the production and operation managers to evaluate the influential factors relating to the machine life length as shown in the figure 5.2 above.

The analysis of the machine life length was performed with the application of the Analytical Hierarchy Process (AHP) and was then compared using the AHP pair-wise comparison process, with the corresponding result showing the calculated percentage of priority from the AHP software to determine the consistency ration of the criteria (see table 5.1) below. The pair-wise comparison and the intensity are shown in appendix 5.
### Influencing Factors
(Life cycle cost element) | Priority (%)
--- | ---
Utilities cost | 48.34
Depreciation cost | 24.57
Maintenance & Operation cost | 17.89
Transportation & Installation cost | 5.97
Disposal cost | 3.23

**Consistency Ratio : 0.116**

*Table 5.1 - Ranking of factors affecting Machine Life Length*

The AHP result above shows that cost associated with utilities, depreciation and maintenance and operation (with respect to the machine) are the three most dominant factors influencing the machine life length considering their weighted priorities. The utilities cost was found to lean the priority of factors (*table 5.1*). The last two criteria (i.e. transportation & installation and disposal cost) were left out because of their low intensity and thus, were not considered as an influencing factors which was also agreed upon by the company’s respondents. After a series of analysis and discussion with the company’s respondents on the weighted factors, the consistency ratio (0.116) that was obtained from the conducted AHP analysis through the AHP software was accepted, indicating that the judgments were reliable and trustworthy. The goes the same with the machine performance related consistency ratio.

#### 5.3. Machine performance

The second major factors relating to the production process in the plant is the machine performance which is influenced by different factors and sub-factors emanating from different working areas in the plant. Nevertheless, based on the scope of this study, factors affecting machine performance with respect to the production process are being considered. After a brainstorming session with production and operation managers, the following key factors as shown in (*figure 5.3*) below were identified to affect machine performance or production efficiency.
The identified factors (figure 5.3) affecting machine performance was weighted and compared using the pair-wise comparison process (see appendix 6). The weighted factors and the consistency ratio was calculated by an AHP software, the result showing the percentage weight in terms of priority from the AHP software is presented in table 5.2.

<table>
<thead>
<tr>
<th>Influencing Factors</th>
<th>Priority (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Usage</td>
<td>41.14</td>
</tr>
<tr>
<td>Machine Stoppage</td>
<td>31.06</td>
</tr>
<tr>
<td>Speed Delays</td>
<td>12.31</td>
</tr>
<tr>
<td>Competence</td>
<td>11.08</td>
</tr>
<tr>
<td>Product Quality</td>
<td>4.42</td>
</tr>
</tbody>
</table>

**Consistency Ratio : 0.166**

*Table 5.2 - Ranking of factors affecting Machine performance*

The result (table 5.2) from the AHP software shows the two dominant factors (i.e. material usage and machine stoppage) affecting machine performance with the material usage leading the priority of factors. The consistency ratio also indicated that the judgments for the weighted factors are trustworthy. Both the production and operation managers were the company’s respondent to this analysis, this outcome of the analysis was agreed upon by them.
The prioritized factors and sub-factors (in bold italics) thought or rather considered to be affecting production efficiency and profitability (with respect to machine life length and machine performance) in the plant is presented in figure 5.4. This was based on the assessment and the analysis performed using the Analytical Hierarchy Process (AHP) pairwise comparison procedure and software to ascertain that the judgments were reliable and trustworthy.

Fig. 5.4 – AHP analysis of the considered factors and sub-factor affecting production profitability

5.4. Costs and benefits associated with prioritized factors

Different costs element are associated with the factors considered to be affecting production profitability in the case plant. Thus, it is of great importance to identify the associated costs before evaluating the losses and benefits that are economically related with the factors. In
doing this, a cost breakdown structure was done in order to show the various costs under each considered factors, i.e. Utilities, Depreciation, Maintenance and operation, Material usage, Machine stoppage). The cost breakdown structure of the prioritized factors connected to both machine life length and machine performance is presented below (figure 5.5).

The concept of cost breakdown structure was retained in the diagram above (figure 5.6) because it provides a good link to the approach/ technique of life cycle cost analysis by clearly showing how the cost are distributed , thus, facilitate easy understanding. The element of the cost breakdown structure of the prioritized factors is based on the cost data collected from the case factory (see appendix 7).

The utilities category contains all the cost required to power and run the machine. This includes cost associated with wood chips, energy, water etc. However, the energy and water cost was highlighted by the company’s respondent, thus, were stated in the cost breakdown structure. The investment on maintenance and operation category contains all the costs to keep the machine running. This includes labor cost, spare parts cost, overhead cost related to

![Fig 5.5 – Cost Breakdown Structure of prioritized factors](image-url)
the plant and maintenance/repair cost. The spare parts costs are usually low (according to the company respondent) due to the warranty from the manufacturer. However, the said warranty is only valid for few months before the company starts computing for spare part.

The machine stoppage category does not have any data associated with it because it is presently not a limitation for the company. However, it will commence when lean and continuous improvement program is implemented. The depreciation category contains the costs which includes the costs relating to machine depreciation. The final category is the material usage. This includes the scrap cost (which is considered to be between 2 - 4%) of the total used material and the cost for the material itself.

5.5. Economic assessment of the benefits and losses of prioritized factors

To account for the impact of maintenance on production profitability which is the scope of this study, the economic evaluation of the prioritized sub-factors is performed in order to see the benefits and losses associated with them (i.e. Utilities, Depreciation, Maintenance and operation, Material usage, Machine stoppage).

Some required data were not received from the production manager except the utility cost for the machine due to the company’s policy. Therefore some fair amount of assumptions was made on all the five factors mentioned above.

i. Savable money from Utilities

Energy and water cost = 6,800,000 SEK/ year (for the machine in the plant)
Machines presently at the plant = 15

Assumptions made on utilities

- It was assume that all the machines (15) in the plant consumes equivalent amount of energy, water etc.
- 5% of the total energy consumed is due to maintenance related energy required
- Yearly increase of 5% in energy consumption
Given that 3 of the machines (out of 15 machines) were considered to be critical machines by the production manager, and the machines operational life length is 10 years, thus, our evaluation will be based on 3 critical machines.

Hence, the utility cost for the considered 3 critical machines in the plant for the first year:

\[ 6,800,000 \times \frac{3}{15} = 1,360,000 \text{ SEK/year} \]

Assuming 5% is accounted for total energy consumed due to maintenance related problems, therefore savable money from utilities = \( 1,360,000 \times 0.05 = 68000 \text{ SEK per year (for year 1)} \)

(See full evaluation for the duration of 10 years in appendix 8)

ii. Investment on maintenance and operations

Spare parts cost = 150,000 SEK/ year

Labor cost = 258,500 SEK/ year

Maintenance/ repair = 1,300,000 SEK/ year

Overhead cost (related to plant) = 17,300,000 SEK/ year, for 24 employees presently at the plant. However, this cannot be accounted for maintenance implementation alone since there are other working areas in the plant.

(NB: all costs listed above accounts for all 15 machines)

Assumptions made on maintenance and operation

- We assume that spare parts cost will increase within the operational life length of the machine, therefore, yearly increase of 5% in spare parts throughout the operational life length (10 years)
- Yearly increase of 5% in labor cost
- 4 personnel in maintenance department
- Yearly increase of 5% in overhead cost

Recalling again that we are only considering 3 critical machines at the plant, we are going to make evaluation for 3 machines considered.

Total spare parts cost for 3 machines: \( 150,000 \times \frac{3}{15} = 30,000 \text{ SEK/year (for year 1)} \)

Total labor cost for 4 workers: \( 258,500 \times 4 = 1034000 \text{ SEK/year (for year 1)} \)

For the evaluation of the overhead cost, it is assumed that 4 employees for the maintenance organization, so we shall calculate for 4 employees. Therefore, if the overhead cost is
17,300,000 (relating to 24 employees), then for 4 employees = 17,300,000*(4/24) = 2,883,333 SEK/year (for year 1)

(See full evaluation for the duration of 10 years in appendix 8)

iii. Saving from depreciation

Depreciation cost for each machine = 400,000 SEK/year
No of machine in the plant = 15
Total investment cost (machines) = 60 million SEK
Total depreciation cost: 400,000*15 = 6,000,000 SEK/year

But since we are also considering the three critical machine earlier mentioned, thus the depreciation for the three machines will be;
Depreciation for 3 machines: 400,000*3 = 1,200,000 SEK/year

The depreciation cost (i.e. 400,000 SEK/year) for each machine indicates that the plant uses straight line depreciation method which implies that the depreciation cost of each machines during the course of time and usage is constant over the life span. This is evident when dividing the total cost of investment on the machine by the (number of machines at the company and the economic life length of the machines).

Nevertheless, total depreciation cannot be accounted for maintenance alone because no matter the level of maintenance, machine depreciation cannot be avoided. Thus we assume that 5% of depreciation expenses accounts for maintenance, i.e. depreciation for 3 machines which is 1,200,000 multiplied by the percentage of depreciation expenses accounted for maintenance (i.e. 1,200,000*0.05 = 60000 SEK/year) (for year 1)

Therefore, to account for the depreciation, double declining balance or 200% which is commonly used in calculating depreciation today was adopted because it presume that the yearly cost of depreciation is a fixed percentage of the net book value in the start of the year by charging higher depreciation in the asset early years. It is computed as follows;
Factor = 2*(1/10) = 0.2
The first year of the depreciation for the 3 critical machines would be = 60000
The second year would then be; 60000*0.2 = 12000
*(See full evaluation for the duration of 10 years in appendix 8)*

iv. Savings from less machine stoppage

Originally, no data was provided for machine stoppages because it was not a limitation for plant. However, the Price/part and the production capacity in 2009 was 6, 18 SEK and 1,000,000 kg respectively. Thus, some assumption was made to justify this aspect. Therefore we assume that;

- 3 stoppages/ week of 2 hours in each stoppages
- Since it is normal to have 5 weeks of vacation in Sweden, therefore, we estimate working time as 47 weeks/ year
- Approximately 10% yearly decrease in machine stoppages

Therefore, for maintenance related stoppages: 3*47*2 = 282 Hrs/ year
Total yearly working hours: 8*5*47 = 1880 Hrs/ year

The total working hours in the plant will account for 1,000,000 kg of product. But there is 2-4% of scrapped parts, we consider the highest percentage which is 4%. Therefore the total product minus 4% of the total product as result of quality defect i.e.

1,000,000 - 0.04* (1,000,000)  
1,000,000 – 40000 = 960000 kg

In 1880 working hour in year, 960000 kg of will be produced

Therefore if 1880 yearly working hours produces 960000 kg, then, 282 Hrs/year of maintenance related stoppages will account for 144000 kg (i.e. 282*960000/1880) which is then multiplied by the part price  
(i.e. 144000*6,18 = 889920 SEK/year)

Machines stoppages for 3 machines = 889920*3 = 2669760 SEK (for year 1)
Therefore, the total amount from less machine stoppages = 2669760 SEK
*(See full evaluation for the duration of 10 years in appendix 8)*
v. Savings from material usage defects

Material cost = 15 SEK/kg
Sales for 2009 = 43,835,000 SEK
Parts sold = 7,096,372
Price/part = 43,835,000/7,096,372 = 6.18 SEK
Planned material usage (for 2010) = 970,000 kg
Scrapped part material = 2-4% of total used material

Assumptions made on material usage

- Yearly increase of 5% in material cost
- 25% of material loss accounted for maintenance

Calculating for material usage losses accounted to maintenance will be
0.04*970,000*15*0.25 = 145500 SEK/year (for year 1)
(See full evaluation for the duration of 10 years in appendix 8)

In the economic evaluation of the sub-factors which were considered to have an effect on the company’s production profitability, we calculated for savings the company might realize when maintenance is implemented in the production process. Such saving would be generated from utilities, depreciation, machine stoppages, material usage (as shown in appendix 8). Thus, if maintenance is properly implemented in the plant, there would be saving for the company from utility cost because, when the machines are functioning properly for example, there will have less energy consumption as to when the machines are not functioning in the right manner. The calculated savings (from the economic evaluation) for utilities when maintenance is implemented is shown below (table 5.3).

<table>
<thead>
<tr>
<th>Years</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savable money from utilities (SEK)</td>
<td>68000</td>
<td>71400</td>
<td>74970</td>
<td>78718.50</td>
<td>82654.43</td>
<td>86787.15</td>
<td>91126.51</td>
<td>95682.83</td>
<td>100466.97</td>
<td>105490.32</td>
</tr>
</tbody>
</table>

Table 5.3 – Savable money from utilities
There would also be lower depreciation rate for the machine if they are maintained throughout their life span, thus, a higher salvage value for the machine when they are finally being sold at the end of its proposed usage life. In addition to that, there would be less down time, higher production efficiency, production quality, timely delivery etc. which increase company’s competitiveness and profitability. The possibility of these factors mentioned and more are guaranteed when the machines are well maintained. Thus, referring to Al-Najjar et al. (2001) that production capacity, machine capability and company’s profitability and competitiveness is influenced by efficient maintenance policy.

The implementation on maintenance and operation is more or less a cost for the company at the early stage due to the fact that it will involve an enormous investment in settling up a good maintenance organization, thus, it is regarded in the economic evaluation table as investment on maintenance and operations. Nevertheless, comparing the investment on maintenance organization in the plant with savings the company would generate from other factors highlighted in relation to the machine life length and machine performance, it is obvious that such investment will be beneficial to the plant on the long run when continually improving maintenance process at the plant. In addition, the implementation of maintenance in the production system is a profit and support function considering the company proposing on implementing lean production/ manufacturing.
6. Results

The main result of the analysis made on the empirical findings in conjunction with the theoretical framework is presented in this chapter.

The analytical framework in the analysis chapter shows that machine life length and machine performance are the two most significant factors that are directly linked with production efficiency which leads to profitability. These two main factors are influenced by numerous sub-factors, however, some sub-factors were found to be having much effect on the life length and performance of which is fundamental to company’s profitability.

Utilities, depreciation, maintenance and operation, machine stoppages and material usage were the defining sub-factors presently found to be affecting production profitability in the plant. The analysis done on these sub-factors using the analytical hierarchy process revealed that these sub-factors were reliable and trustworthy based on the consistency ratio obtains from the analytical hierarchy process software.

Different costs and benefits elements associated with the prioritized sub-factors were shown through the cost breakdown structure in order to make visible the cost element of the indentified sub-factors. The economic evaluation on the prioritized sub-factors describes the savings that could be associated with utilities, depreciation, machine stoppages and material usage defect with respect to maintenance implementation in the production system. However, maintenance implementation in the production system in the sense is considered an investment because establishing a good maintenance organization involves investing some money.

On the whole, the benefit that is associated with implementing maintenance in the plant is enormous when compared to the cost of investing on maintenance (which can only be seen as cost at the earlier stage of implementation) because it is not visible to identify and quantify its impact on company’s business. In contrast, the profits that organization stands to benefit with the implementation of maintenance in production system cannot be compared to the investment on implementing maintenance in the plant.
The financial gains the company will benefit when maintenance is fully implemented in the plant are product of the economic evaluation on the prioritized factor in the previous chapter. To show the financial gains with respect to maintenance implementation in the plant, the yearly sum of the investment on maintenance in the plant (i.e. investment on maintenance and operation) is subtracted from the yearly savings that will be generated with maintenance implemented (i.e. savable money from utilities, savings from depreciation, savings from less machine stoppages, savings from material usage defects) as shown in (table 6.1) below

<table>
<thead>
<tr>
<th>Years</th>
<th>Yearly savings</th>
<th>Yearly investment /cost</th>
<th>Yearly financial benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2943260</td>
<td>3947333</td>
<td>-1004073</td>
</tr>
<tr>
<td>2</td>
<td>3172911</td>
<td>4144699.7</td>
<td>-971788.65</td>
</tr>
<tr>
<td>3</td>
<td>3468193.35</td>
<td>4351934.63</td>
<td>-883741.283</td>
</tr>
<tr>
<td>4</td>
<td>3801083.5</td>
<td>4569531.36</td>
<td>-768447.867</td>
</tr>
<tr>
<td>5</td>
<td>4168402.2</td>
<td>4798007.932</td>
<td>-629605.732</td>
</tr>
<tr>
<td>6</td>
<td>4572180.491</td>
<td>5037908.329</td>
<td>-465727.838</td>
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<tr>
<td>7</td>
<td>5015756.955</td>
<td>5289803.745</td>
<td>-274046.791</td>
</tr>
<tr>
<td>8</td>
<td>5503023.673</td>
<td>5554293.933</td>
<td>-51270.25953</td>
</tr>
<tr>
<td>9</td>
<td>6038304.552</td>
<td>5832008.629</td>
<td>206295.9229</td>
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<tr>
<td>10</td>
<td>6626363.032</td>
<td>6123609.061</td>
<td>502753.9716</td>
</tr>
</tbody>
</table>

Table 6.1 – Yearly financial gains/ losses

From the table above (table 6.1) it is observed that the yearly financial benefits column has a negative signs which indicate losses (until the ninth year) instead of positive signs (maybe at
the second or third year) considering that there should be financial benefits with the implantation of maintenance. However, the negative signs could be due to the following reasons.

1. There is higher investment at the earlier stage of maintenance implementation
2. Because more aspect in the company that maintenance could affects are not incorporated in the evaluations.
3. Variation in the figures based on assumed values relating to practical situations and implementation of less accurate measurements
4. The fact that the machines are new is also a factor accounting for the visibility of maintenance impact.
5. The fact that the calculation was performed for 10 years of economic life time could also be a factor. However the implementation of maintenance could prolong the economic life time, thus, the savings will be very much visible in the later years.
7. Conclusions

The final conclusion which is the answer to the problem formulation of this study and recommendations are presented in this chapter.

This study describes the role of maintenance as a support function and its impact on production efficiency with respect to the life length and performance of production equipments which is fundamental in achieving production profitability. Maintenance as a function in a production system/ an organization can increase production efficiency, reduce downtime or unwanted stoppages, improve product quality and consequently, plant profitability which is one of the most significant motivations of company’s investment.

Maintenance implementation in a production system can improve production profitability in numerous ways by reducing production process interference. In manufacturing environment, a production system is a company core process because it produces goods/ products which when sold, keeps the company in business. In ensuring that expected production or products are delivered at the right time with the right quality and the lowest possible cost requires optimum availability which can be attain by efficient maintenance policy. A proper maintenance practice can keep machines/ equipments (that constitute a production system) in a reliable machine condition, thus, minimizing production inefficiency, product defects, downtime, etc. thus, an hour spent not working as a result of unwanted stoppages or machine defect can be costly when transferred into financial terms, thereby threatening company’s survival to stay in business.

As the industrial sector continue to be more capital intense as oppose to the labor intense, production form/ pattern is also taking a different form (i.e. from mass production to various variety of production) maintenance interaction with other working areas in an organization such as quality, production, competence working environment, safety requirement etc. has increased by contributing to the reduction of losses associated with production and in addition, increasing the quality of the end product, thus, increasing company’s return on investment (ROI) and competitive advantage.
7.1. Recommendation

Based on what have been discussed throughout this study which is the impact of maintenance on company’s productivity and profitability, it is clear that maintenance is not just about ensuring proper function of production equipment but also a support function that is indispensable in a manufacturing organization. Hence, from the study result, it is recommended that the SCA (Urshult plant) treats maintenance as a core function of company’s business, thus, with a holistic view, its impact on product quality, cost reduction, product quality, availability, environmental and safety requirements can be identified and quantified.

That being said, having a maintenance organization should be considered in the plant to further outline maintenance significant and its role in production profitability. Thus, the implementation of maintenance in the plant is inevitable as this study and several others have shown that maintenance is a core function and essential in today’s production system in order to reduce production losses, product defect and downtime, at the same time increasing production capacity and product quality to maximize company’s profitability.
8. Reference

Literatures that were used to conduct this study are listed below accordingly.


• EN 13306: 2001 – Maintenance Terminology


• Henrichsen, L., Smith, M. T., & Baker, D. S. (1997). Taming the research beast: Research methods in TESL & Language Acquisition, BYU Dept. of Linguistics USA.


Internet -
  
  • (www.allbusiness.com, assessed 24th May, 2010)
  • (www.cci-icc.gc.ca/tools/ahp/index_e.asp, assessed 26th April, 2010 )

Interviewed personnel
  
  • Raimo Michelsen
    Production Manager SCA Packaging Sweden AB
    Division Cellplast, Urshult.

  • Joachim Nordberg
    Operation Manager SCA Packaging Sweden AB
    Division Cellplast, Urshult.
9. Appendix

Appendix 1 – Expandable polystyrene (EPS) also referred to as bead

Appendix 2 – Silos (place where the beads are stored/ rested after pre-expending)
## Appendix 3 - EPS production process flow

### PROCESSFLÖDE EPS, NEOPOR TEKNISK PRODUKT

<table>
<thead>
<tr>
<th>Process/Status</th>
<th>Nr.</th>
<th>Arbetssprocess</th>
<th>Produkt/Process Egenskaper</th>
<th>Kontrollmetod</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>O</td>
<td>Godsmottagning</td>
<td>Fraktsedel</td>
<td>3.4.1.1</td>
</tr>
<tr>
<td>2</td>
<td>O</td>
<td>Ankomstkontroll</td>
<td>Certifikat, Följesedel</td>
<td>3.4.1.1</td>
</tr>
<tr>
<td>3</td>
<td>O</td>
<td>Interntransport</td>
<td>-</td>
<td>3.4.1.1</td>
</tr>
<tr>
<td>4</td>
<td>O</td>
<td>Lagringsplats</td>
<td>-</td>
<td>3.4.1.1</td>
</tr>
<tr>
<td>5</td>
<td>O</td>
<td>Interntransport</td>
<td>-</td>
<td>3.4.1.1</td>
</tr>
<tr>
<td>6</td>
<td>O</td>
<td>Förskummning</td>
<td>Recept</td>
<td>3.4.3</td>
</tr>
<tr>
<td>7</td>
<td>L</td>
<td>Kontrav densitet</td>
<td>Förskummningsprotokoll</td>
<td>3.4.3.1</td>
</tr>
<tr>
<td>8</td>
<td>L</td>
<td>Silos</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>O</td>
<td>Verktygsbyte</td>
<td>Produktionsförberedelse</td>
<td>3.4.2</td>
</tr>
<tr>
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<td>Grundinstallation maskin</td>
<td>Produktionsförberedelse</td>
<td>3.4.2</td>
</tr>
<tr>
<td>11</td>
<td>O</td>
<td>Verifikation av installation och 1.a bits kontrol</td>
<td>Formgjutning</td>
<td>Kontrollinstruktion</td>
</tr>
<tr>
<td>12</td>
<td>O</td>
<td>Produktion</td>
<td>SPC</td>
<td>7.2.42 + 7.2.53</td>
</tr>
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<td>O</td>
<td>Processkontroll</td>
<td>Utseende</td>
<td>Kontrollinstruktion</td>
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<tr>
<td>14</td>
<td>O</td>
<td>Packning och märkning</td>
<td>Emballering och etikettering</td>
<td>Packinstruktion</td>
</tr>
<tr>
<td>15</td>
<td>O</td>
<td>Inrapportering</td>
<td>MPS-system</td>
<td>3.4.5</td>
</tr>
<tr>
<td>16</td>
<td>O</td>
<td>Interntransport</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>17</td>
<td>O</td>
<td>Lagringsplats</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>O</td>
<td>Utleverans kund</td>
<td>Utleveranslista</td>
<td>3.4.6.1</td>
</tr>
</tbody>
</table>
Appendix 4 – Fundamental scale for pair wise comparison used in the AHP analysis

<table>
<thead>
<tr>
<th>Intensity of Importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two elements contribute equally to the objective</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance</td>
<td>Experience and judgment slightly favor one element over another</td>
</tr>
<tr>
<td>5</td>
<td>Strong importance</td>
<td>Experience and judgment strongly favor one element over another</td>
</tr>
<tr>
<td>7</td>
<td>Very strong importance</td>
<td>One element is favored very strongly over another; its dominance is demonstrated in practice</td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td>The evidence favoring one element over another is of the highest possible order of affirmation</td>
</tr>
</tbody>
</table>

Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.

Appendix 5 - Pair-wise comparison and priority percentage table for Machine Life Length

<table>
<thead>
<tr>
<th>Criteria A</th>
<th>Criteria B</th>
<th>Intensity</th>
<th>Priority (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance &amp; Operation</td>
<td>Disposal</td>
<td>7</td>
<td>Utilities = 48.34</td>
</tr>
<tr>
<td>Maintenance &amp; Operation</td>
<td>Transport &amp; Installation</td>
<td>7</td>
<td>Depreciation = 24.57</td>
</tr>
<tr>
<td>Maintenance &amp; Operation</td>
<td>Utilities</td>
<td>-5</td>
<td>Maintenance. &amp; Operation = 17.89</td>
</tr>
<tr>
<td>Maintenance &amp; Operation</td>
<td>Depreciation</td>
<td>-3</td>
<td>Transport &amp; Installation = 5.97</td>
</tr>
<tr>
<td>Disposal</td>
<td>Transport &amp; Installation</td>
<td>-3</td>
<td>Disposal = 3</td>
</tr>
<tr>
<td>Disposal</td>
<td>Utilities</td>
<td>-9</td>
<td></td>
</tr>
<tr>
<td>Disposal</td>
<td>Depreciation</td>
<td>-7</td>
<td>Consistency Ratio : 0.116</td>
</tr>
<tr>
<td>Transport &amp; Installation</td>
<td>Utilities</td>
<td>-7</td>
<td></td>
</tr>
<tr>
<td>Transport &amp; Installation</td>
<td>Depreciation</td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td>Depreciation</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 6 - Pair-wise comparison and priority percentage table for Machine Performance

<table>
<thead>
<tr>
<th>Criteria A</th>
<th>Criteria B</th>
<th>Intensity</th>
<th>Priority (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Quality</td>
<td>Material Usage</td>
<td>-5</td>
<td>Material Usage = 41.14</td>
</tr>
<tr>
<td>Product Quality</td>
<td>Machine Stoppage</td>
<td>-7</td>
<td>Machine Stoppages = 31.06</td>
</tr>
<tr>
<td>Product Quality</td>
<td>Speed Delays</td>
<td>-3</td>
<td>Speed Delays = 12.31</td>
</tr>
<tr>
<td>Product Quality</td>
<td>Competence</td>
<td>-5</td>
<td>Competence = 11.08</td>
</tr>
<tr>
<td>Material Usage</td>
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Appendix 7 – Questions for SCA Packaging Sweden AB, Urshult

1. What are the utilities cost associates with the machine?
   a. What utility cost do you have in mind? Is it wood chips, electricity, water and so on?
      i. If so: Energy & Water-cost, 6.800.000 SEK/year

2. What are the machine depreciation cost and the economic life length?
   a. Each machine has a depreciation of 400.000 SEK/year. In this is included the total installation with plumbing, pipes electricity, start-up and the machine itself.
      i. We have 15 machines today.

3. What are the cost associated with maintenance and operation (e.g. the labor cost, spare parts cost, overhead cost and maybe maintenance system implementation cost if there is any)?
   a. Spare part costs are very low due to the warranty. Close to 0 SEK. The warranty is valid for 4-5 months more, and after that we calculate the spare part cost for
150,000 SEK/year for all machines. You can use this number in the calculation.

b. Labor cost for preventive maintenance on the moulding machines is 62,000 SEK/year for all machines.

c. The total cost for maintenance/repair is 1,300,000 SEK/year.

d. Overhead cost related to the plant is 17,300,000 SEK/year

4. What is the material usage rate (for quality defected products)?
   a. Reuse of “scrapped parts”-material is somewhere between 2-4% of total used material in moulding.

5. What is the material cost and material usage cost
   a. Material cost is right now 15 SEK/kg and we plan to use 970,000 kg this year.

6. What is the machine stoppage data? And the economic stoppage measurement of the machine?
   a. We do not have any stoppage data on the machines today. The stoppage is not a limitation for us today, and therefore not highlighted. We assume that it will be highlighted within a year, and collecting of stoppage data will probably start when we implement LEAN and the program of continues improvements.
## Appendix 8 - Element of economic evaluation

<table>
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<tr>
<th>Years</th>
<th>Savable money from Utilities (Energy and water cost)</th>
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<th>Yearly sum (SEK/ yr)</th>
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<th>Savings from machine stoppages</th>
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