CHALMERS
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Reducing Paper Waste to Improve Resource Efficiency at a Swedish Printing and Packaging Company

Master's thesis in the Master Degree Program Quality and Operations Management

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Abstract

The printing industry faces pressures to increase efficiency and reduce cost due to global overcapacity and rising costs of raw material. At the same time increased legislative and customer demands to lower the environmental impact of industry activities has created a need for printers to better their sustainable practices. Increasing resource efficiency and reducing waste has therefore become an important aspect to consider for printers wanting to maintain their market position in an increasingly competitive environment.

In the printing industry discarded paper is one of the largest sources of waste and is associated with substantial costs and environmental impact. Finding ways to reduce paper waste can therefore present opportunities for printers wanting to become more efficient, engage in more sustainable production and lower costs. Based on this, the purpose of this thesis is to map the current paper waste situation at a Swedish printing and packaging company, investigate its causes and suggest an approach for how paper waste can be reduced at the company. The research strategy of this thesis combines both qualitative and quantitative methods including observations, interviews, production data analysis, and production measurements.

The findings reveal that a majority of the paper waste at the company originates from the cutting and offset printing departments. Approximately 42 % of the total generated paper waste originated from the cutting department, and at least 24 % originated from the offset printing department. It was however also found that the potential to reduce paper waste exists in all investigated production steps. Causes of paper waste differ between departments and waste types but main factors influencing paper waste include: a lacking focus on waste reduction, missing accountability for waste generation, a mindset where waste is seen as a necessary and integral part of production, and a difficulty of accurately assessing the paper needed throughout production due to lack of process measurements and accurate production data. It was also found that current imposition practices in combination with using mainly two sheet sizes, inefficient inventory control practices, and lacking housekeeping practices affects the generation of paper waste largely.

From the findings it is concluded that reducing paper waste is a complex and cross-functional endeavor which requires continuous efforts if real improvements are to be realized and sustained. Reducing paper waste must become prioritized within the organization and the view of paper waste as necessary altered. Accountability for waste generation should be established, and the environmental strategy and goals anchored in daily shop-floor operations. Accurate production data needs to be made available so that the production process can be monitored and controlled, and continuous improvements enabled. Common reduction techniques such as reusing wasted paper and improving inventory control practices should also be explored.

Acknowledgement

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We would like to thank the employees at the company who have been involved in this thesis for their support and willingness to share opinions and precious information. Without their valuable contribution this project would not have been possible.

Furthermore we would like to give a special thanks to our supervisor at the case company and our supervisor at Chalmers Peter Almström for their valuable feedback, interesting discussions and advice which has guided us throughout this process.

Glossary

Words that are fundamental for the understanding of this thesis and specific for the printing industry are defined below. The Swedish equivalent of the word is presented in italics when applicable.

Gross number of sheets	The estimated number of sheets needed to complete an order. The gross number of sheets is calculated to cover anticipated make-ready spoilage and include the net number of sheets. *Bruttoark.*
Net number of sheets	The number of sheets required to produce the ordered amount of copies and to cover spoilage and faults in post-printing operations. *Nettoark.*
Make-ready sheets	Sample sheets needed to set-up printing presses to reach and maintain a high quality of print throughout the printing process. *Inställningsark.*
Overs	Additional copies of printed materials than ordered produced to allow for set-up operations and faults during the printing and finishing processes. *Överexemplar.*
Imposition	The process of arranging individual pages in final printing position on a press sheet. *Utskjutning.*
Offset printing	An indirect printing technique where an intermediate surface (a rubber blanket) is used to transfer ink from printing plates onto the printing surface. *Offsettryck.*
Sheet fed offset printing	An offset printing technique where printing is done on individual sheets of paper as they are fed to the press one at a time. *Arkoffset.*
Pagination	Sequenced page numbering. *Paginering.*
Signature	A sheet on which several pages has been printed, which has been folded so that pages are arranged into their proper numbered sequence and thereby make up a section of a book.

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1. Introduction

In this section the background, purpose, limitations, problem analysis and research questions of the thesis are presented.

1.1 Background

During the past two decades sustainability performance has become an increasingly important component of companies' competitiveness, due to increased stringent environmental policies, the link between environmental performance and long-term cost reduction, and the fulfillment of regulatory requirements (Despeisse et al., 2012). However, much of today's natural resources are used in an unsustainable manner and end up as waste. Using excess raw materials, poor resource utilization, scrap parts and outdated materials all contribute to organizations waste streams and take a toll on both the environment and the finances of a company (Franchetti, 2009). To tackle these problems and approach sustainable development, waste management practices have been developed (El-Haggar, 2007). Waste management activities can include the collection, transportation, treatment and disposal of waste, as well as monitoring and regulating the production process to prevent waste generation and to support reuse and recycling (OECD, 2003). The environmental performance of a process is influenced by five factors: input material, technology, execution of the process, the product and waste and emissions (Nilson et al., 2007). Corresponding actions to reduce wastes are therefore changes or substitutions of input material, technology and product changes or modifications, good operating practices, and recycling activities (Nilson et al., 2007).

In the printing industry pressures to adopt more sustainable practices have become increasingly important because of, among other things, customer and legislative demands to lower the environmental impact of its activities (Thompson, 2014). Today printers face pressures to reduce costs due to worldwide overcapacity and rising costs of raw material and energy (Thompson, 2014). Waste management has therefore become one of, if not the biggest environmental issue facing organizations within the printing industry today (Thornhill, 2014). By using resources more efficiently and reducing wastes, printing companies can increase their chance of maintaining their position in an increasingly fierce market environment (Envirowise, 2004).

The case company is a Swedish printing and packaging company in great need of reducing the amount of paper wasted in their operations. At present, there are high costs associated with the generated paper waste, indicated by substantial differences between the amounts of purchased raw material compared with the amount of paper utilized in the final products. Paper accounts for approximately 30% of production costs, and on average 35% of purchased raw material is scrapped. Furthermore, during the first ten months of 2015, paper waste accounted for 70% of the total quantity of waste generated by the company. Given the large amount of waste and its associated costs, efforts to minimize the paper waste and increase process efficiency have become issues discussed by top management. Reductions of paper waste levels can have a significant financial impact for the company and will also benefit their ecological footprint and sustainability performance. However, at present there exists no detailed or comprehensive view over the paper waste situation. Therefore, the efforts needed to mitigate the generation of paper waste and where they need to be focused are currently unknown.

1.2 Purpose

The purpose of this thesis is to give a detailed view over the case company's paper waste situation, identify its causes and to propose future efforts to reduce paper waste quantities.

1.3 Problem analysis and research questions

To keep track of paper waste, the company has established a performance indicator that puts the amount of paper retrieved by their recycling partner in relation to the amount of purchased paper on a month-by-month basis. The paper waste performance indicator paints a general picture of the current situation but misses to convey more specific information about where and how much paper waste is generated in different steps of production. The lack of detailed information about waste quantities and waste streams makes paper waste a difficult issue to handle, and has given rise to an internally divided view of the importance of the topic. To be able to better work with decreasing paper waste and build consensus in the matter, there is a need to determine where paper waste originates in the production system, and to identify which paper waste types that contribute largely to the total waste stream, in order to know where efforts should be focused. The first question to guide the research is therefore:

1) Where in the production process is paper waste generated and what are the main waste types that contribute to the paper waste stream?

Understanding where paper waste is generated and which the main paper waste types are is important, but without understanding why paper waste is generated real improvements are difficult to realize. An awareness of what causes paper waste is a prerequisite to tackle the problem at the source and to generate solutions that can be sustained in the long-term. Currently a comprehensive view of what causes paper waste does not exist. In some areas of production, causes of paper waste are better understood than in others but the subject needs to be investigated further to get a complete picture. Therefore the second research question is:

2) What are the main causes of paper waste generation at the company?

When the current paper waste situation at the company is better understood, the newly acquired knowledge can be used to guide future waste reducing efforts. Suggestions on actions required to proceed with the paper waste problematic will therefore be given. The third research question is consequently:

3) What actions need to be taken by the company in order to reduce current paper waste quantities?

1.4 Delimitations

This thesis will focus only on the paper waste generated at the case company and therefore exclude other types of wastes generated when printing such as inks, scrap metal and chemicals.

The company has several production sites in Sweden, however due to resource and time constraints, this thesis is limited to focus on only one of the production plants. Furthermore it focuses only on paper waste generated in offset production and the bindery since the bulk of the paper waste is generated within these departments, thereby excluding paper waste from digital printing. Moreover, packaging paper and office paper will not be considered in this thesis as these paper types differ from the paper used in offset production and the bindery, and therefore do not generate the same type of waste.

Industrial waste includes all solid, liquid and gaseous waste generated from the production of goods (Shen, 1995). However as this study is focused on the solid waste generation of paper, the theoretical review has focused on solid waste reductions, and therefore methods of reducing liquid or gaseous wastes will not be thoroughly discussed throughout the report. Furthermore, since factors such as machine park, production layout and product design are seen as given, technology and product changes will not be suggested as means to reduce waste. Therefore, waste reduction alternatives connected to product and technology changes have been excluded from the study. Lastly, the actual implementation of improvements will not be part of the thesis, however improvement suggestions and how these can be sustained will be discussed.

2. Theoretical framework

In this section the theoretical framework of the study will be presented. First theory on waste management and related practices will be introduced, followed by the presentation of general frameworks for assessing waste reduction opportunities in production.

2.1 Waste Management

Waste management is an umbrella expression incorporating all activities needed to manage waste, from conception to final disposal. Waste management activities can include, as previously mentioned, the collection, transportation, treatment and disposal of waste, as well as monitoring and regulating the production process to prevent waste generation and to support reuse and recycling (OECD, 2003). Waste management methods vary significantly across organizations, countries, regions and sectors (Davidson, 2013), as individual waste management methods are not capable of handling all types of waste in a sustainable way (Davidson, 2013; McDougall et al., 2008). When exploring different waste management methods the waste management hierarchy can be used as a guide since it classifies waste management options according to their desirability (Nilson et al., 2007). The hierarchy indicates a preferred order of action to reduce and manage waste in terms of their environmental impact and sustainability (Davidson, 2013). Different versions of the waste management hierarchy exist, but all share fundamental characteristics and convey the same essence (Davidson, 2013; UNEP, 2013; El-Haggar, 2007). In 2008 the European Union (EU) adopted a five-step version of the waste management hierarchy acting as the cornerstone of the Waste Framework Directive. The directive guides waste legislation and policy within all member states in the EU, and requires member states to adopt national waste management plans and waste prevention programs based on the hierarchy (EU, 2008). Figure 1 depicts the EUs version of the waste management hierarchy.

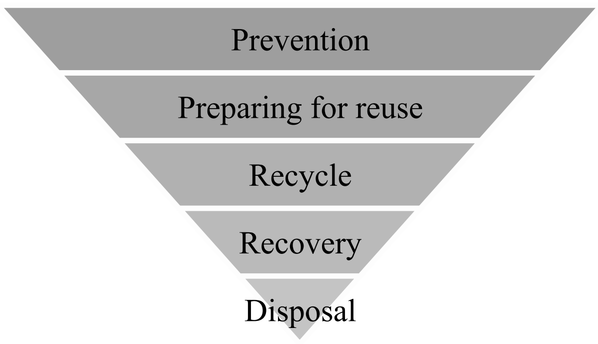

Figure 1. The EUs Waste Management Hierarchy (EU, 2008).

A rigid use of the waste management hierarchies is not recommended, instead they should be regarded as guiding references or frameworks to identify sustainable waste management options (Price and Joseph, 2000). The most sustainable solutions are therefore not provided for all particular waste streams by the hierarchies (McDougall et al., 2008). Instead environmental, economical and social effects of options need to be evaluated altogether for specific waste streams in order to find optimal solutions (McDougall et al., 2008).

Actions preventing the generation of waste and pollution are preferred and highest prioritized among waste management options (UNEP, 2013). Prevention is the most effective way to eliminate waste (Davidson, 2013), and represents the most efficient and sustainable use of resources (EU, 2012). The underlying rationale being that if waste is not generated in the first place, the associated problems do not need to be managed at all. Prevention, which is also known as source reduction, includes all efforts to reduce waste quantities, harmful or toxic substances, and the negative effects of waste on the environment and human health (EU, 2008; EPA, 2015a). Furthermore, it includes the reuse of material or products, and/or the extension of a product's lifespan (EU, 2008; EPA, 2015a). The activities must however take place before a substance, material or product has become waste (EU, 2008; EPA, 2015a). Next in the hierarchy is preparing for reuse, which entails operations or practices that check, clean or repair products or components that have already become waste into being re-usable without requiring any further pre-processing operations (EU, 2008). Recycling is the third preferred action in the waste management hierarchy and encompasses the reprocessing of wastes into new substances or products, which are to be reused either on-site or off-site (EU, 2012).

When none of the more sustainable methods of the hierarchy are possible, recovery of energy is the next preferred alternative. This level in the hierarchies includes waste-to-energy methods where energy is recovered from materials through for example incineration (EU, 2012). The least preferred action in the waste hierarchies is disposal, either in landfills or incineration without energy recovery (UNEP, 2013; EU, 2012). Disposal is to be considered a last resort for waste when no preceding options in the hierarchy are feasible (UNEP, 2013).

2.1.1 Waste Minimization, Pollution Prevention and Cleaner production

Closely tied to the waste hierarchy, and important methods of waste management, are the concepts of Waste Minimization (WM), Pollution Prevention (P2) and Cleaner Production (CP). It is generally acknowledged that the strategies encompasses, more or less, the first, second and third levels of the waste management hierarchy. The methods represents a shift in focus from the traditional practices of pollution control i.e. treatment and disposal of generated waste, to prevention of wastes i.e. source reduction (Shen, 1995). The fundamental view of the strategies is that avoiding waste generation is often more cost-effective and sustainable than traditional practices of controlling and disposing of waste after its generation (Khor et al., 2007). Consequently, these methods of waste management concentrate on the prevention of waste being created, thereby reflecting a proactive approach towards waste management. However, this does not imply that pollution or waste control practices will never be required, but that at least the dependence on such solutions are decreased (UNEP/DEPA, 2000). The specific definitions of the different concepts are presented in table 1, but they can all be broadly defined as practices which reduce or eliminate the creation of pollutants and wastes at the source (Khor et al., 2007). EPA's definition of P2 excludes recycling and reuse of recovered material used as input to other processes than those the material was originally intended for, while WM and CP commonly include these practices. However, other authors have chosen to include all recycling and reuse activities as P2 practices, as such efforts also entail a reduction in waste material quantities (Bishop, 2000; Khor et al., 2007). The broader adaptation of P2, which includes recycling and reuse, is adopted throughout this report.

Table 1. Generally accepted definitions of Waste Minimization, Pollution Prevention and Cleaner Production.

Waste minimization has been defined in EPA's report to Congress in 1986 as: *"The reduction, to the extent feasible, of hazardous waste that is generated or subsequently treated, stored, or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either: (1) the reduction of total volume or quantity of hazardous waste or (2) the reduction of toxicity of hazardous waste, or both, so long as the reduction is consistent with the goal of minimizing present and future threats to human health and the environment."* (EPA, 1988, p. 2).
EPA has defined pollution Prevention as: *"the use of material, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. It includes practices that reduce the use of hazardous materials, energy, water or other resources and practices that protect natural resources through conservation or more efficient use"* (Bishop, 2000, p. 11).
Cleaner Production was defined by UNEP in 1990 as: *"The continuous application of an integrated environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment"* (Tsai et al., 2015, p.60).

Waste reduction techniques

Waste reductions can be achieved by utilizing different reduction techniques, and the ones applied in industry today can be broadly categorized into source reduction and recycling techniques (Shadiya et al., 2012). In line with the logic of the waste hierarchy WM, P2 and CP advocates that waste management practices should be elevated to the higher levels included in the concepts (Crittenden and Kolaczkowski, 1995). Thereby, when evaluating improvement options source reduction practices should be explored first, and then followed by recycling alternatives (Smith, 2004). Source reduction entails changes to either a product or a process that reduces the volume or toxicity of waste (EPA, 1992). Common source reduction methods are presented in figure 2. Input material changes and improved operating practices will be described further below, but product and technology changes will not as these have been excluded from the study, as motivated in chapter 1.3.

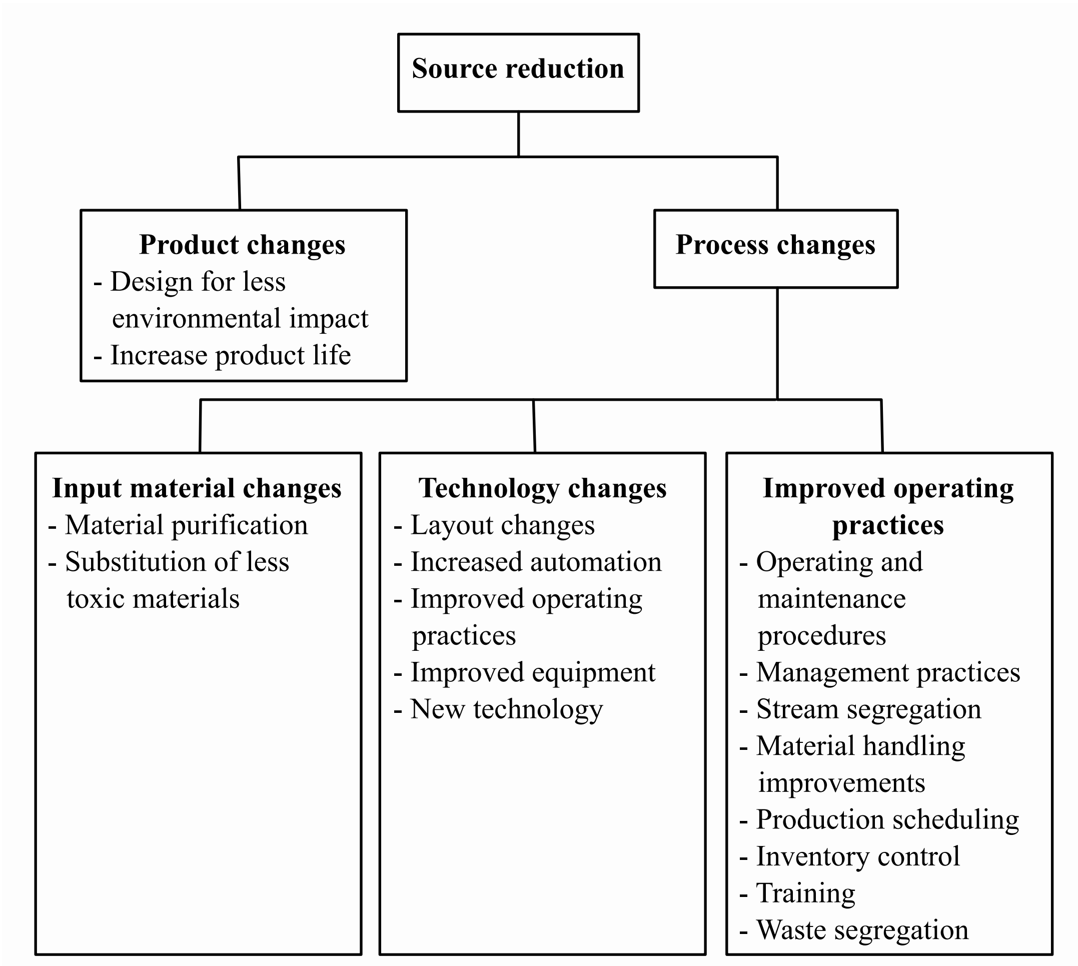

Figure 2. Source reduction methods (EPA, 1992, p.6)

Input material changes reduces waste from entering, or avoids the generation of waste within the manufacturing process (Smith, 2004) and entails substituting or purifying input material (Crittenden and Kolaczkowski, 1995; EPA, 1988), see figure 2. Examples of practices are reducing the toxicity of waste by switching to less toxic solvents, or to use more efficient inputs to processes so that less material or energy is used during manufacturing (Shen, 1995). Customers can also largely affect the choice of input material. A strategy to reduce waste can therefore be to provide customers with information and pricing signals, which encourage decisions that reduce environmental impact (Franchetti, 2009). This is important as customer choices and specifications often can affect the environmental performance of a production process to a significant extent (Franchetti, 2009).

Good operating practices are, simply explained, techniques that optimize raw material consumption in the production process (Hunt, 1991). This category of source reduction techniques relates to changes in procedures and organizational aspect of operations, and is institutionalized through better plant management or improved housekeeping practices (Cheremisinoff and Ferrante, 2013). Typically these measures can be implemented at a lower cost and quicker than other source reduction techniques (EPA, 1992), through for example procedural instructions in production, maintenance, storage and material handling (El-Haggar, 2007).

A common initial prevention activity is to conduct an environmental assessment (Shen, 1995). Assessments are useful tools for diagnosing how a facility can minimize wastes; it enables companies to effectively target areas with great improvement potentials as it helps to identify where and how much waste is generated in specific steps of the process (Shen, 1995). A detailed description of an environmental assessment will be presented in chapter 2.2.2.

By deploying good practices in relation to material handling and storage, great improvements can often be made (Shen, 1995). Improvements to material purchasing, receiving, inventory and handling practices can decrease the amounts of expired, leftover or unneeded material, and/or accidental generations of wastes that occur (Khor et al., 2007). Examples of good inventory control practices are "Just-in-time" (JIT) procurement, which entails purchasing what is needed, when it is needed and in the right amount; and to track material consumption, through e.g. barcoding, which enables procurement quantities to be limited as information on stored material is known (Weinrach, 2001).

Improving management practices in order to minimize waste can entail the implementation of a reduction program at an executive level aimed at holding department and plant managers accountable for reporting on quantities of wastes from their respective departments (Cheremisinoff and Ferrante, 2013). It is important to establish accountability for waste generation if changes are to be made (Franchetti, 2009). However, it is also important to create incentives for reductions (Franchetti, 2009). Incentive programs towards quantity reductions are in themselves not classified as source reduction methods, but as increased awareness can result from such efforts waste reductions may be obtained (Cheremisinoff and Ferrante, 2013).

The generation of waste can also be affected by training programs, which for example can address storage procedures; reporting, housekeeping and material management practices (Shen, 1995); waste segregations; and how to use equipment properly (Cheremisinoff and Ferrante, 2013). Awareness and employee training programs are important factors to reach full potential of waste reduction efforts, as for example people with process knowledge often generate the best improvement ideas (Weinrach, 2001).

Other operating practices that reduce waste are preventive maintenance programs and improved production scheduling (EPA, 1992). Maintenance programs that focus on preventive actions can decrease the generation of waste caused by equipment failure (Hunt, 1991), and prevent the occurrence of leaks and spills or other accidental generations of wastes (Khor et al., 2007). Improvements in production scheduling can reduce equipment cleaning and setup material used between batches or production runs (Hunt, 1991).

The segregation of waste and waste streams is also an important factor to consider, as such practices can increase the recyclability and reusability of waste, and thereby improve environmental performance (Cheremisinoff and Ferrante, 2013). Collection and sorting practices can have a significant impact on the economic and environmental performance of the entire waste management system (Davidson, 2013). The practices of recycling and reusing waste material as input for the same process, or for other processes or uses within the same facility, is preferred over off-site recycling alternatives (Vanatta, 2000). On-site recycling and reuse can even be regarded as a source reduction technique (Vanatta, 2000). Two types of equipment are usually needed for the effective management of waste: collection equipment for the gathering of waste and processing equipment for reducing the volume of waste material and for storage (CCME, 1996). Furthermore, larger organizations often require external waste service providers, which transports the waste off-site for either recycling, recovery and/or disposal (Davidson, 2013).

Within the printing industry the practices mentioned above are often used, such as improved housekeeping practices and inventory control practices, to prevent and reduce waste generation (AEBN, 2003; WMRC, 1997). However, more specific recommendations for reducing paper waste within lithographic printing include:

- Using both sides of make-ready sheets (AEBN, 2003; WMRC, 1997).
- Efficient and effective scheduling, such as running similar jobs after each other, as this reduces make-ready and changeover spill (WMRC, 1997).
- Improving accuracy of counting methods to reduce excess quantities printed to accommodate inaccuracies (WMRC, 1997).
- Designing layouts to fit sheet sizes in order reduce paper waste in cutting and binding operations (WMRC, 1997).
- Reusing waste paper (WMRC, 1997).
- Using scrap paper for press setup (Franchetti, 2009).
- Waste accounting; collect accurate data on waste from each source/press, establish accountability, provide incentives for reduction, and provide feedback on waste reduction performances to employees (WMRC, 1997).
- Storing paper in the right conditions and properly conditioning paper to pressroom temperature and humidity (WMRC, 1997).
- Set up goals for make-ready sheets and regularly track and compare make-ready waste figures to the set goals to minimize waste (City of Tulsa, 2007).

Benefits of waste reductions

There are several benefits that can be obtained from the implementation of WM, P2 and CP strategies and techniques, including direct economic and environmental benefits (Crittenden and Kolaczkowski, 1995; EPA, 1988; Franchetti, 2009; Shen, 1995; UNEP/DEPA, 2000). Waste represents both energy and material resource losses, and can be an indication of inefficient and unsustainable production processes (Staniskis and Stasiskiene, 2005). Waste management efforts can therefore provide direct economic benefits, as reducing the amount of waste produced commonly coincides with increased efficiency, productivity and profitability (Weinrach, 2001). Cost savings are derived from the avoidance of waste hauling and handling activities, less purchased material, and revenues obtained from the sale of recyclables (Franchetti, 2009; Visvanathan, 2007; EPA, 1992; UNEP, 1991).

Waste minimizations also provides several environmental benefits as it decreases the need to harvest new material, saves energy, reduces greenhouse gas emissions and waste quantities that needs to be recycled, recovered or disposed (EPA, 2015b). Furthermore, recycling practices also result in less waste in landfills and the conservation of energy and natural resources (Franchetti, 2009; Tchobanoglous and Kreith, 2002). Waste management efforts can also assist in the achievement and improvement of regulatory requirements and therefore reduce the regulatory burden and risk of receiving fines (Crittenden and Kolaczkowski, 1995; Cheremisinoff, 2003; EPA, 1992), thereby reducing environmental liability risks (EPA, 1988; Franchetti, 2009; Shen, 1995; UNEP/DEPA, 2000).

Besides economic, environmental and liability risk benefits, personal and social benefits of stakeholder can be obtained (Franchetti, 2009; UNEP/DEPA, 2000). The well being of employees can increase as cleaner facilities often results from reduction activities, moreover helping the environment can provide personal satisfaction for stakeholder (Franchetti, 2009). Furthermore, the application of sustainable practices can improve corporate image and attract new environmentally conscious customers, employees and partners who share the same values (Franchetti, 2009).

Barriers to waste reduction efforts

The main potential barriers that can hinder the implementation of waste reduction activities and efforts are economic, regulatory, technical and cultural aspects (Crittenden and Kolaczkowski, 1995). Waste reduction efforts often provide benefits in the long-term, and as environmental activities seldom have clear-cut budgets set aside, competing for funding with other projects that provide short-term benefits presents an obstacle (Sharma, 2001). If larger monetary investments are needed, the less tangible benefits of reduction efforts should be included when assessing economical feasibility, such as allocating waste disposal and handling costs to specific operations (Crittenden and Kolaczkowski, 1995). Regulatory barriers might seem unlikely as waste minimization efforts should decrease the environmental burden, but undertaking process changes may involve alterations to licenses or other regulatory approvals (Crittenden and Kolaczkowski, 1995). However, since one of the main goals of waste management initiatives is to benefit the environment, these barriers are often relatively easy to overcome by working with regulatory bodies during planning processes (Crittenden and Kolaczkowski, 1995).

A lack of sufficient process and engineering knowledge of production techniques are great technical obstacles to successful waste reduction implementations and efforts (Crittenden and Kolaczkowski, 1995; Visvanathan, 2007). Inevitably there are risks involved when changes are made to industrial processes, thus it is common that concerns regarding the risk of affecting the quality of the product and/or customer acceptance arises (Crittenden and Kolaczkowski, 1995). Production personnel and other stakeholders can therefore easily turn down new procedures due the risks associated with process changes if the improvement facilitator lacks sufficient knowledge of the process (Sharma, 2001). Furthermore, as production stoppages and new bottlenecks can arise, process changes should always be pilot tested and the feasibility and efficiency of changes assessed (Crittenden and Kolaczkowski, 1995).

The greatest challenges when implementing waste reduction techniques are however often cultural and connected to organizational resistance (Sharma, 2001). In a study performed by the AEBN (2003), it was concluded that reduction improvements and process efficiency requires management change, as resistance to change was identified as the main obstacle for improving waste management practices within printing companies. Attitudinal changes in directors, managers and employees are often crucial in order to obtain the most from reduction methodologies (UNEP/DEPA, 2000). Resistance to change can arise for several different reasons such as lack of senior management commitment, insufficient awareness of corporate goals and objectives, poor internal communication, inadequate training, inflexible organizational structures and bureaucracy (Crittenden and Kolaczkowski, 1995). Moreover, as people disconnected from the production floor often set environmental programs or strategies, and employees connected to production mostly focus on keeping the manufacturing line up and running, making process changes to benefit the environment are often neglected (Sharma, 2001). In a benchmarking study performed within the Australian printing industry (AEBN, 2003) it was concluded that senior management support and commitment down the management chain are crucial for waste management improvements to be realized. Furthermore, in many organisations environmental concerns are often combined with environmental regulations, and as regulations often are prioritized higher due to the risk of receiving a notice of violation, other environmental concerns are often overlooked (Sharma, 2001). Therefore it is important to clearly define and incorporate environmental responsibilities into job descriptions in order for environmental efforts to not be disregarded and for waste management programs to reach their full potential (Sharma, 2001).

2.2 Waste Reduction Audits

A waste reduction audit is a methodology that helps to identify areas of inefficient resource consumptions and poor management of waste within an organization (UNEP/DEPA, 2000), and provides a solid foundation for a practical and successful implementation of a waste reduction program (Khor et al., 2007). Understanding how, why and where wastes are generated in the production process is a prerequisite for effectively preventing or reducing industrial wastes (UNEP, 1991). Knowing where wastes originate and problems arise in the process enables areas to be identified where waste reduction and cost saving is possible (UNEP, 1991). Therefore, an integral part of many waste reduction programs or strategies is to perform a Waste Minimization Opportunity Assessment (WMOA), also referred to as a Pollution Prevention Opportunity Assessment, Cleaner Production Assessment, solid waste assessment, waste-minimization audit or green audit (EPA, 1988; UNEP, 1991; Van Berkel, 1994; Mulholland and Dyer, 2001; Sharma, 2001; Franchetti, 2009; Visvanathan, 2007).

A WMOA is a systematic framework used to identify waste minimization opportunities, and is often presented as a structured step-by-step program with intermediate milestones (Sharma, 2001) and can be a starting point for investigating pollution issues at any facility (Avşar and Demirer, 2008). A WMOA generates a comprehensive understanding of a facility's processes and wastes, identifies waste reduction opportunities and evaluates the feasibility of their implementation (Sharma, 2001). The rationale behind WMOA procedures is that accurate information about the origins and sources of waste is a prerequisite for effective waste reduction (UNEP, 1991). Once the sources are identified the most effective options for avoiding and reducing wastes can be identified (UNEP, 1991). The WMOA procedure involves measuring, observing and recording data, and incorporates collecting and analyzing waste samples (UNEP, 1991). The assessment procedure can be performed on different levels depending on its purpose; on a regional level it can point out problematic industries; on plant level wastes can be tied to specific processes; and on process level, root causes and exact origins of wastes can be identified (UNEP, 1991).

Over the years, a number of generic qualitative frameworks describing how to conduct a WMOA have been developed. Authors include the United States Environmental Protection Agency (EPA, 1988; EPA, 1992), the United Nations Environment Programme (UNEP, 1991), Khor et. al (2007), Visvanathan (2007), and Franchetti (2009). The frameworks present similar qualitative evaluation programs aimed at identifying waste minimization opportunities at industrial scale (Musee et al., 2007), and share key characteristics. Despite differences in terminology and structures between the WMOA frameworks Van Berkel (1994), Van Berkel et al. (1997), and Sharma (2001) argue that many of the frameworks describe the same generic process, and can therefore be represented by the four-step procedure originally developed by the EPA (1988). Figure 3 depicts the main activities of the above-mentioned generic frameworks categorized into these four phases. In the following chapter the phases are explained in greater detail.

Planning and Organization Phase
- Gain management support for waste minimization project
- Establish project team
- Set focus and scope of project
- Identify overall project goals

⇩

Assessment Phase
- Pre-assessment
  - Collect baseline facility and process information
  - Conduct plant walk-through
  - Generate process flow-diagrams
- Assessment
  - Determine process inputs & outputs
  - Derive material balance
  - Generate waste minimization options
  - Conduct preliminary screening of options

⇩

Feasibility Analysis Phase
- Conduct technical, environmental and economical evaluation of options
- Select and prioritize options for implementation

⇩

Implementation Phase
- Design waste reduction action plan
- Justify projects to management and obtain funding
- Install necessary equipment and implement procedures
- Evaluate performance of implemented alternatives

Figure 3. Generic steps of a WMOA framework. Adapted from EPA (1988), UNEP (1991), Visvanathan (2007) and Franchetti (2009).

2.2.1 Planning and organization

The first step of a WMOA is to thoroughly prepare the organization for the audit exercise so that it is carried out within budget and time, and with as little interference to normal plant activities as possible (Visvanathan, 2007). Main undertakings in this phase include forming a project team, gaining management support and commitment and defining scope and goals of the audit (EPA, 1988; UNEP, 1991). A prerequisite for a successful WMOA is that top management shows support for the project and that employees are involved and made aware of the initiative (Visvanathan, 2007). Top management should establish a formal commitment throughout the organization, and waste minimization should be communicated to be an important focus of the company (EPA, 1988). This can be done by releasing a formal policy statement or a memo that highlights the importance of the new waste minimization initiative and encourages staff to take part and contribute (Franchetti, 2009). Using bonuses, prizes and other forms of recognition are common ways to raise motivation and participation among employees (EPA, 1988). Using posters to inform about the pollution scenario at the company, and about the benefits, objectives and goals of the waste minimization initiative can also help boost staff interest and involvement (Visvanathan, 2007).

Another key element in the preparatory work for a waste audit is forming a team responsible for all subsequent WMOA work (Visvanathan, 2007). The team can range from a few people with contributions from employees in a small factory, to many people including environmental specialists, production employees and technical staff, all depending on size and complexity of the process that will be studied (UNEP, 1991). The EPA (1988) suggests that at least two people should be involved in the team to obtain a variety of perspectives and viewpoints. For the team to have a higher degree of authority in the organization and swifter communication with management, the team leader should be in a managing position (Franchetti, 2009).

Before undertaking the actual auditing process the scope and focus of the audit needs to be established (Franchetti, 2009). The scope and focus depend on the main objectives and goals of the waste audit (UNEP, 1991). If the scope is not aligned with the goals of the waste minimization project, audit efforts may go to waste (Visvanathan, 2007). The purpose of having project goals and objectives is to provide specific direction for the audit and they should therefore be measurable, realistic and achievable (Visvanathan, 2007). Also, if the project objectives are not clear and precise enough, there is a risk that they merely become vague and generalized improvement slogans, unable to provide the direction needed (Franchetti, 2009).

Audit objectives often stem from determining the major problems and wastes associated with the specific production process (UNEP, 1991). Objectives may for example include minimizing raw material losses and reducing wastes for which disposal costs are high or for which regulations exist (UNEP, 1991). Other common waste audit objectives are to reduce toxic and hazardous wastes and to improve operational health and safety (Visvanathan, 2007). An audit can have the objective to look at waste minimization as a whole and therefore focus on a complete production process, or in other cases the main concern might be a specific waste stream, motivating a more narrow focus on specific unit operations (UNEP, 1991). The audit frameworks provide general guidelines for identifying waste reduction opportunities and should therefore be altered to fit the specific needs of a company or situation (UNEP, 1991).

2.2.2 Assessment

The purpose of the assessment phase is to get a detailed understanding of facility operations and waste streams, and to identify and screen waste minimization options (EPA, 1988). Generating such a comprehensive understanding requires the collection and compiling of baseline information from a wide variety of sources, sometimes ranging over the entire cross-section of the facility (Visvanathan, 2007). A commonly suggested first step in this phase is therefore to review existing process and facility data such as process flow diagrams, operating manuals, raw material invoices, purchasing and inventory logs, and recycling records (UNEP, 1991; EPA, 1988). Examining existing organizational records regarding processes, operations and waste management practices provides the team with important background information, helps them determine areas of interest and may reveal opportunities to minimize wastes (EPA, 1988). Useful sources of information for this step are organizational data, material and product data, raw material and logistic consumption data, process data, environmental data, management data, financial data and industry data (Visvanathan, 2007).

Facility Walk Through

An important part of generating baseline information is to conduct a thorough walkthrough of the entire manufacturing plant so that a true picture of all processing operations and their interrelationships can be had (UNEP, 1991). The walkthrough should follow the material flow through the facility, from storage of raw material to the storage of final products, without skipping any process step (Visvanathan, 2007). During the plant tour, team members should examine all production activities, and key figures and facts so that nothing is overlooked, as even trivial observations may be useful at a later stage (Visvanathan, 2007). This includes taking detailed notes of observations and discussions; sketching process layouts, material flows and site plans; and consulting plant employees about normal operating conditions (UNEP, 1991). Conversations with production staff may reveal important information regarding actual operating procedures, waste discharge points, unplanned wastes such as spills, and process problems (UNEP, 1991).

Constructing Process Flow Diagrams

A crucial step in gaining detailed insight into the production processes is constructing process flow diagrams, through which important process steps are visualized, and sources of waste generation identified (Franchetti, 2009; UNEP, 1991; Visvanathan, 2007; EPA, 1988). The purpose of the process flow diagram is to help the audit team fully comprehend the business processes and capabilities of the production site so that well-grounded alternatives to minimize waste may be developed (Franchetti, 2009). A process flow diagram visually represents the workflow of a process or an entire operation, and is made up of a set of activities that transform well-defined inputs to outputs (Franchetti, 2009). The diagram should be founded on baseline data collected through a plant tour and existing records review, and should contain information from the unit operations relevant to the project (Visvanathan, 2007). The detail level required to achieve the project objectives is important to consider when constructing a process flow diagram (UNEP, 1991). The less detailed or the larger the audit becomes, crucial information tends to become oversimplified or be lacking altogether in the process flow diagram, undermining its purpose (UNEP, 1991).

Generating a material balance

Next a detailed account of inputs and outputs for target processes should be determined so that waste streams, their composition, and previously unknown material losses can be quantified (Franchetti, 2009; EPA, 1988; UNEP, 1991; Visvanathan, 2007). Proposed methods to achieve abovementioned goals include generating a material balance (EPA, 1988; UNEP, 1991; Visvanathan, 2007) or conducting a facility waste sort (Franchetti, 2009). Both methods entail similar data collection methods and share the ultimate goal of generating a base of information from which waste minimization options can be identified (Franchetti, 2009; UNEP, 1991; Visvanathan, 2007; EPA, 1988).

Generating a material balance to characterize waste streams can require great effort but often results in a more detailed picture of the waste situation (EPA, 1988), and highlights areas of concern where e.g. information is inaccurate or lacking (Visvanathan, 2007). Moreover, a material balance helps focus waste minimization activities and provides a baseline for measuring performance (EPA, 1988). Generating a material balance starts by determining and quantifying inputs such as raw materials, chemicals, air and water to the processes and each unit operation (UNEP, 1991). A first step in doing so is to study raw material purchasing records and to examine storage and material handling operations. This to get an understanding of the net input to the process as raw material losses often arise from storage and handling practices (UNEP, 1991). Raw material consumption rates of the relevant unit operations should also be determined, which may require taking measurements and making observations in production and deriving average consumption figures (UNEP, 1991).

The second half of a material balance entails quantifying process outputs. Outputs include products and by-products, as well as solid and liquid wastes, including those which may need to be transported off-site for treatment and disposal (Visvanathan, 2007). Quantifying outputs often entails reviewing company records of products and wastes sent off-site, and measuring production rates over a period of time (UNEP, 1991).

The material balance is generated by comparing input figures with output figures. Ideally they should equal each other, but this is rarely the case in practice (Visvanathan, 2007). Arriving at an accurate material balance requires refining collected data and being aware of factors that could over- or underestimate waste streams (Visvanathan, 2007). A significant material imbalance can point to potential material losses or waste discharges, but can also be a result of measurement errors or overlooked material flows (UNEP, 1991). To obtain a satisfactory material balance some data collection activities may need to be repeated, and unit operations re-examined (UNEP, 1991). Reviewing and complementing collected data may be crucial in obtaining an accurate and comprehensive picture of the material flows, which is a prerequisite for a successful waste audit and waste reduction action plan (UNEP, 1991).

Identify Waste Minimization Options

The material balance helps describe the nature of wastes and material flows in the production process, and can help identify areas of concern, sources of wastes and areas of unexplained losses (UNEP, 1991). With the information from the material balance and site inspection as foundation, possible ways to minimize waste in the assessed area can be identified (Visvanathan, 2007). An effective way to generate waste minimization alternatives is to use brainstorming or other group decision techniques in an environment which encourages creativity and independent thinking (EPA, 1988). Discussing with plant engineers and operators, equipment manufacturers, trade associations, and environmental consultants, as well as benchmarking and using literature may also provide the team with valuable input for creating alternatives (Franchetti, 2009). The process of conceiving waste minimization alternatives should follow the waste management hierarchy discussed in chapter 2.1 so that options preventing waste generation are explored first (EPA, 1988).

Waste minimization options can be divided into two categories depending on their requirements in terms of effort, time and financial resources: obvious measures, and long-term measures (Visvanathan, 2007). Obvious waste-reduction measures are cheap and quick to implement and require little effort. They are simple adjustments that may increase efficiency, and often target unnecessary material losses (UNEP, 1991). These obvious options can include improved management techniques and tightening up housekeeping procedures (Visvanathan, 2007) such as those for ordering, receiving, handling and storing materials (UNEP, 1991). However, certain waste problems may require more than simple procedural changes and improved housekeeping practices to solve. In these cases implementing long-term reduction options involving significant modifications to, for example, production processes, equipment, technology, and raw material types may be necessary (UNEP, 1991).

Screening Waste Minimization Alternatives

In a successful WMOA many waste minimization alternatives will be identified (EPA, 1988). Evaluating the economical and technical feasibility of all alternatives would be very costly and time consuming, which is why a quick screening procedure is put in place to identify options with the highest potential to minimize waste and reduce costs (Franchetti, 2009). Screening procedures can range from an informal evaluation where the assessment team selects the best alternatives based on group discussions, to more formal quantitative methods such as the weighted sum method (EPA, 1988) and the House of Quality (Franchetti, 2009). An informal evaluation works best when only a few minimization options have been generated, and quantitative methods are recommended when a large number of alternatives exist (EPA, 1988). To be effective, a screening procedure should consider the main implications of each generated option, including the expected reduction of waste and raw material consumption, cost and ease of implementation, and impact on employee moral (Franchetti, 2009). The result from the screening procedure indicates which options are suitable for a more thorough feasibility analysis (EPA, 1988).

2.2.3 Feasibility Analysis

When waste reduction opportunities have been screened and prioritized the remaining alternatives need to be further evaluated and ranked based on their economical and environmental impact, and technological feasibility (EPA, 1988). In this step it is important to consider the main objectives and goals of the project, and to which extent the waste minimization options will fulfill them (Franchetti, 2009). Evaluating some options may require substantial analysis and may include reaching out to vendors for additional equipment information or analyzing market trends for recyclable commodities (Franchetti, 2009). The advantages of other waste minimization options may be more obvious and require little analysis to identify, in which case they can be ready for implementation without rigorous evaluation efforts (EPA, 1988). Such options can for example be procedural and housekeeping changes that require small investments and can be implemented quickly (EPA, 1992).

Technical Evaluation

Technical feasibility concerns assessing if the required resources to implement a waste minimization option exist within the organization, or if they can be reasonably acquired (Franchetti, 2007). This includes investigating the option's compatibility with current operating procedures, employee skill level, quality requirements and its general impact on the production processes (Visvanathan, 2007). During a technical evaluation both production requirements and facility constraints need to be taken into account (Franchetti, 2007). Common criteria used to evaluate the technical feasibility of a waste minimization option are listed in table 2. Major changes to equipment, processes or materials often require large capital expenditures, and may impact production rates and product quality (EPA, 1992). Options requiring such changes therefore need to be evaluated more thoroughly (Franchetti, 2007). To ensure an options viability and acceptance all affected groups should contribute to the evaluation (EPA, 1988). This may include consulting people from production, purchasing, and maintenance, but can also include talking to customers to verify their requirements (EPA, 1992). All substantial changes should be piloted and tested before full scale implementation and integration with current production setup is undertaken (Visvanathan, 2007). If an option is deemed impractical or does not meet the technical requirements of the organization after a technical evaluation, it should be dropped from further consideration (EPA, 1988).

Table 2. Commonly used criteria when evaluating the technical feasibility of a waste minimization option. Adapted from Franchetti (2007) and EPA (1998).

Technical evaluation criteria	
● Available space in facility ● Effect on production schedule ● Effect on worker safety ● Effect on product quality ● Compatibility with operating procedures, workflow, material handling and production rates	● Implementation time ● Required skills and knowledge ● Additional labor, training and education requirements ● Utility requirements ● Impact on product marketing ● Available services from vendor

Environmental Evaluation

An environmental evaluation entails comparing pros and cons of each waste minimization alternative with regards to the environment. In some cases the environmental benefit of an option is obvious, but sometimes the reduction of one waste may generate other problems resulting in an overall environmental disadvantage (UNEP, 1991). Therefore, many aspects of the environmental impact of an option should be considered before its implementation. This may include conducting life cycle assessments, gathering information on raw material extraction and transportation, and treatment of any unavoidable waste (EPA, 1992). Other things to consider are: how the option affects volume and contamination of wastes; if it changes toxicity, degradability or treatability of wastes; and whether it uses more or less non-renewable resources and energy than current options (UNEP, 1991). Usually the environmental benefits of housekeeping and direct efficiency improvements are straightforward and easy to assess, while the effects of options involving process, product or raw material changes are more difficult to evaluate and need more thorough analysis (EPA, 1992).

Economical Evaluation

Another essential criteria to assess is the economic feasibility of the waste reduction options. This involves calculating the capital, operation and maintenance costs associated with each option, and the estimated savings and revenues they are expected to generate (Visvanathan, 2007). The goal is to compare the financial effects of implementing the waste reduction options with the existing situation and to determine if the new option makes economical sense (UNEP, 1991). Determining the economic viability of reduction alternatives commonly includes the use of traditional financial performance indicators such as payback period, net present value and internal rate of return (Franchetti, 2007). However, more holistic evaluation methods which capture the direct, indirect and less-tangible environmental costs and benefits that traditional accounting procedures miss can also be used (EPA, 1992). Such methods include Total Cost Assessment, which describes internal costs and savings, and includes environmental criteria; and Life Cycle Costing, which considers all internal and external costs associated with the entire life cycle of a product, process or activity (EPA, 2001).

2.2.4 Implementation

The last phase of the audit includes the implementation of selected options, and ensuring that the results are continuously monitored (UNEP/DEPA, 2000). When the waste reduction options have been evaluated, the remaining viable alternatives should provide the basis for a waste reduction action plan (UNEP, 1991). The plan gives a detailed description of how each minimization alternative will be implemented and includes an implementation timeline, necessary site preparations and operational activities required for a successful execution (Franchetti, 2007). The effectiveness of the implemented options should also be evaluated, typical indicators used are for example reductions in wastes and resource consumption per unit production (UNEP/DEPA, 2000). Therefore, periodic monitoring is required to determine whether positive changes are occurring and whether the company is progressing toward its targets (UNEP/DEPA, 2000). When options have been identified and implemented, these needs to be evaluated to see if the desired results were obtained, if so the appropriate steps to secure the gains should be taken (Bergman and Klefsjö, 2010). Improvements needs to be consolidated through for example standardization i.e. introduction of new standard procedures (Bergman and Klefsjö, 2010).

Another part of the implementation phase is to get support for the implementation from top management and to secure funding for the suggested alternatives. This may require necessary project investments to be comprehensively justified, and additional data to be gathered and presented in order to convince key decision-makers (EPA, 1992). It is recommended that the reduction options be implemented slowly and consistently in stages so that employees have time to adjust to the changes (UNEP, 1991), and the impact on production processes and finances can be kept low (Visvanathan, 2007).

By comparing the initial goals of the implemented options to their actual performance, an evaluation of their effectiveness can be made (EPA, 1988). If goals are not met or performances are worse than expected, the options may require modifications or rework (Franchetti, 2007). To keep employees motivated and involved in the changes, training program and reward systems can be put in place (UNEP, 1991). Ensuring that information about upcoming changes and their underlying reasons has been clearly communicated may also reduce workforce resistance and increase their buy-in to the projects (Franchetti, 2007).

2.3 Continuous improvements and employee commitment

WM, P2 and CP programs should be seen as continuing rather than one-time efforts, and should therefore be periodically repeated (EPA, 1988; Visvanathan, 2007). The continuous application of an integrated environmental strategy is crucial in order to approach sustainability and minimize wastes (de Ron, 1998). The assessment frameworks recommend that the audit process should be repeated after identified improvements have been implemented (EPA, 1988), see figure 4. Furthermore, sustained improvements are best achieved if they become a part of the management culture through a formal organizational environmental management system, as such a system provides a decision-making structure and action plan to support continuous improvements (UNEP/DEPA, 2000). If an organization already deploys an environmental management system, reduction assessments can be an effective tool for focusing attention on specific environmental problems, otherwise the assessment can provide the base for an environmental management system (UNEP/DEPA, 2000).

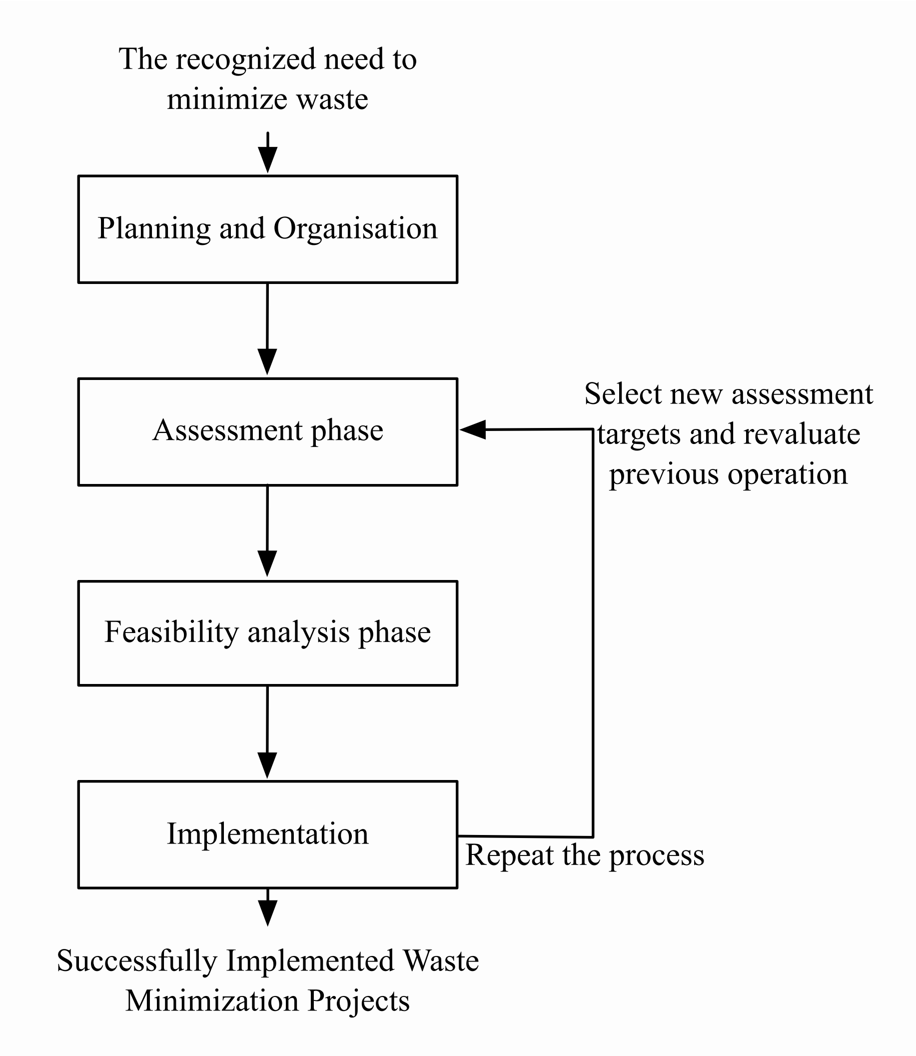

Figure 4. The waste minimization assessment procedure adopted from EPA (1990, p.2).

Furthermore, if reduction programs are to be implemented, there is often a need for cultural changes in order to gain support for the implementation, such as ensuring employee participation and cross-functional integration (Kitazawa and Sarkis, 2000). Empowering employees in combination with using team-based approaches helps to generate ideas and improvements, and cross-functional integrations ensures that changes in one part of the organization does not negatively affect other parts (Kitazawa and Sarkis, 2000). Employee participation, commitment and motivation can be obtained through the delegation of responsibility and authority (Bergman and Klefsjö, 2010), see figure 5. Communication also plays an essential role here, if workers are given the chance to do a good job and given recognition after performing well, employee commitment can be obtained (Bergman and Klefsjö, 2010). Removing obstacles for participations is also important in order to create conditions for employee participation, organizations therefore need to facilitate opportunities for all employees to participate in decision-making processes and improvement work (Bergman and Klefsjö, 2010).

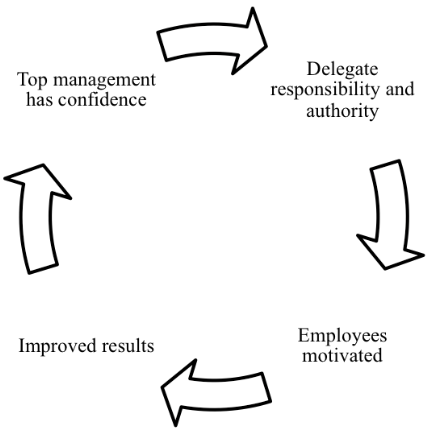

Figure 5. The effect of delegating responsibility and authority (Bergman and Klefsjö, 2010, p. 47).

3. Method

In this chapter the applied research strategy, research design and research approach will be presented. The qualitative and quantitative research methods used and the process of the study will also be described. Moreover, how the gathered data has been analyzed, how a high quality of research can be assured and ethical considerations are also addressed.

3.1 Research strategy, approach and design

A research strategy concerns the general orientation of research and the way it is to be conducted (Bryman and Bell, 2011). In the area of business research two primary research strategies exist: qualitative and quantitative. A qualitative research strategy is characterized by having a strong focus on words rather than quantifications in gathering and analyzing data (Bryman and Bell, 2011). A quantitative research strategy on the other hand empathizes empirical investigations and is primarily concerned with the collection and analysis of numerical data (Bryman and Bell, 2011). The two strategies are however not incompatible and can be united in a so-called mixed methods research strategy (Bryman and Bell, 2011). Bryman and Bell (2011) propose that mixed methods research is suitable when a quantitative or qualitative method alone will not generate the data needed. Dubois and Gadde (2014) argue that when undertaking case research a mixed methods strategy is recommended. This to fully be able to understand the complex reality of the studied case as "[…] *no single approach can capture reality in all its aspects*" (Dubois and Gadde, 2014, p.1282). Since this research incorporates the quantification of paper waste as well as the generation of an in-depth understanding of the waste situation at the company, both qualitative and quantitative research methods have been applied and a mixed methods research strategy adopted. The goal of employing both quantitative and qualitative methods have been to provide a more comprehensive picture of the complex organizational issues that waste management involves.

A single case study research design has been applied during this master thesis. This type of research design entails the detailed and intensive analysis of a single case, such as a single organization, location, person or event (Bryman and Bell, 2011). This thesis will focus on analyzing the specifics and complexities of the main process at a single production site with the hope of generating new theoretical and practical insights to the area of waste management at the company. Through a comprehensive and detailed description of the single case, the findings of the study can hopefully be useful not only for the production site in focus but for other production units within the same organization or even by other business within the printing industry. Several authors underline the benefits of engaging in a single-case study, arguing that the in-depth understanding of complex structures, rich background descriptions and contexts which can be obtained through a single-case study often out-weigh what is lost in generalizability and comparative insights (Dubois and Gadde, 2002; Dyer and Wilkins, 1991; Peattie, 2001; Weick, 2007).

The abductive research approach of 'systematic combining' developed by Dubois and Gadde (2002) have been deployed in this thesis. The authors describe systematic combining as "[…] *a process where theoretical framework, empirical fieldwork, and case analysis evolve simul-*

taneously […]" (Dubois and Gadde, 2002, p.554). The authors further argue that by constantly alternating between different types of research activities and between empirical investigations and theory, a deeper understanding of both theory and empirical phenomena can be had (Dubois and Gadde, 2002). Systematic combining was deemed suitable for this study as it was necessary to alternate between empirical fieldwork and case analysis in order to find logical next steps. Furthermore, developing the theoretical framework in combination with the empirical study and analysis, made the study more efficient as it takes time to gain access to organizational resources.

3.2 Research methods and data collection

Both qualitative and quantitative methods have been used, and information extracted from both primary and secondary sources. Qualitative information was mainly collected through interviews and observations, while quantitative information was extracted from company databases and collected through measurements performed in production. A review of literature has also been conducted throughout the study with the goal to provide relevant topic knowledge and help frame the research process. The research methods and how they have been used in this study is presented in further detail below.

3.2.1 Literature study

A literature study has been performed throughout the course of this thesis to gain deeper knowledge within the areas of waste management and waste auditing, to guide the research design, and to direct the collection and analysis of data. A literature review aims at building an analytical framework and to gain insight into relevant research available within the studied topic (Cronin et al., 2008). A review of relevant literature informs researchers on how to collect data and supports an informed way to analyze the data through the development of a theoretical and analytical framework (Bryman and Bell, 2011). The approach for the literature review followed Cronin et al's. (2008) five steps of a literature review process, and is presented in table 3.

Table 3. The literature review process (Cronin et al., 2008)

Selecting a review topic	The literature search was guided by the purpose and the research questions formulated for the study. The main topics of the literature review have therefore been waste management, waste minimization, pollution prevention, cleaner production and waste auditing or assessment procedures.
Searching the literature	Relevant literature has mainly been found through searches in the Chalmers University of Technology's library online databases and Google Scholar, through combinations of keywords such as ´waste minimization´, ´waste management´, ´cleaner production´, ´sustainable production´, ´pollution prevention´ and ´waste audit/assessment´. Snowball sampling has been used, which entails

	back-tracing reference lists to find new sources of information, to identify more relevant articles and guide the literature review forward (Bryman and Bell, 2011)
Gathering, reading and analyzing the literature	An initial browse of gathered literature was always conducted in order to deem if the material should be further reviewed or not. Relevant literature was then reviewed in a more systematic and critical way so that it could be analyzed and summarized.
Writing the review	The theory of waste management and its underlying concepts was briefly presented, along with waste minimization, pollution prevention, cleaner production and the benefits and barriers connected to such initiatives. Then waste audits have been reviewed and key characteristics of different audit approaches summarized.
References	All references used in this paper can be found in the reference list.

3.2.2 Participant observations

During most parts of the project the researchers have been working from the company site and have engaged almost daily in observations of the production system and working procedures. The observations were conducted in an overt manner and the role of the researchers has been as participant-as-observer. This entails that the researchers have been involved in regular interactions with employees at the company and participated in daily activities (Bryman and Bell, 2011). Initial observations helped build knowledge about organizational culture, current state of the paper waste situation and the daily operations and activities at the company. Throughout the study observations were also used to complement and validate already collected information, and to gain a deeper understanding of subjects of interest. Notes were taken during the project to document observations, as it is risky to rely on the human memory alone (Bryman and Bell, 2011). The notes included summaries of events and behavior and also reflections from the researcher (Bryman and Bell, 2011). Both researchers have taken notes individually during the course of the project, which have included both objective and subjective impressions and understandings. A shared journal has also been kept throughout the project to be able to backtrack the research process and document findings.

3.2.3 Interviews

To gain a deeper insight into the paper waste problematic, qualitative interviews have been held with employees from different departments and from different levels of the organizational hierarchy at the case company. Interviews were conducted with quality and environmental managers; directors of the bindery, offset printing and logistics; production foremen, planners and operators; logistics personnel; the production controller; and personnel from the recycling partner. Conversations were also held with employees from other departments such as sales and economy, however these were spontaneous and occurred due to the fact that the researchers were immersed in the company setting, and can rather be seen as part of the participant observation.

Throughout the project both unstructured and semi-structured interviews were held, depending on the intent and depth of the interview. The purpose of the interviews shifted on a case-by-case basis, depending on where in the research process the interview occurred. The unstructured interviews tended to very similar to a normal conversation, although a predefined topic or question had been prepared by the researchers. The researchers were involved in day-to-day activities at the company and interviews were held ad-hoc. Semi-structured interviews were conducted in cases when the goal was to obtain a deeper understanding of specific problems or areas connected to the paper waste problematic. All interviews have been held face-to-face, where one of the researchers conducted the interview while the other took notes. Notes were taken in order to not only capture what was said but also to capture the attitude and viewpoints of the interviewee. Qualitative interviewing i.e. unstructured and semi-structured interviewing, were chosen as it provides a degree of flexibility during interviews and is an effective way to capture knowledge and experiences of the interviewees (Bryman and Bell, 2011).

How people contributing with information to the study are chosen are important aspects to consider when interviewing (Denscombe, 2009). In this study interview objects were chosen through the use of three selection methods; convenience sampling, snowball sampling and subjective sampling. Convenience sampling entails that suitable interview subjects are selected based on convenient accessibility and proximity; the subjects are chosen because they are easy to recruit (Denscombe, 2009). Snowball sampling implies that respondents recommend other suitable interviewees with the information, experience or knowledge needed (Bryman and Bell, 2011; Denscombe, 2009). Subjective sampling entails that the researcher chooses the person he or she believes to be appropriate for the interview and therefore handpicks interviewees (Denscombe, 2009).

3.2.4 Reviewing existing sources of information

Reviewing existing quantitative data can be used to complement information collected from interviews and observations (Bryman and Bell, 2011). Both existing qualitative and quantitative data was explored including organizational charts, stock balances, purchasing records, recycling invoices, compiled production figures, standard operating procedures and internal reports. This secondary data was used to gain an in-depth understanding of current operating performance and production quantities, and to verify primary data. The existing data was collected from the company and their recycling partner.

Some aspects should be considered when existing data is used: the data should be fairly recent, current conditions should be the same as when the data was collected, and how and when the data was collected should be known (George et al., 2005). Current operating conditions at the company have been in place since the beginning of 2015, therefore secondary quantitative data generated earlier than 2015 has not been considered in this study.

A thorough attempt to analyze the trustworthiness and accuracy of the secondary data was made by assessing how it had been collected and comparing it to other available sources of data. Issues with the quality of some secondary data were found, making it unable to serve its initial purpose. However, these previously unknown issues gave new insights and provided a deeper understanding of the current situation.

3.2.5 In-process measurements and calculations

To be able to estimate the amount of paper waste produced in the studied parts of production, specific input, output and process data had to be manually collected, measured and compiled. The objective of the data collection was to derive a preliminary material balance with focus on paper and paper waste in production. The goal was to investigate what happens to the paper in production by quantifying process inputs and outputs, so that causes of paper waste could be identified and main areas of concern pointed out. A measurement plan was generated explaining how paper usage and paper waste would be calculated and quantified, who would do the required measuring, and during what period of time data would be collected. The important aspects of the measurement plan are presented and explain in section 4.3 in conjunction with the results.

3.3 Research process

The theoretical framework, empirical fieldwork, and case analysis have evolved simultaneously throughout the project. However in the description of the research process below the literature study will not be included as it is explained in detail in chapter 3.2.1 instead. The research process has been greatly influenced by the waste audit frameworks presented and discussed in chapter 2.2. However, to enhance the relevance and usefulness of the frameworks they have been adapted to fit the objectives, limitations and context of this specific case study. The research process can be broadly divided into three parts or phases, described below.

Phase I: Framing the thesis and launching the project

The first part of the project was influenced by the main characteristics found in the planning and organization phase in waste audit frameworks, such as defining scope and goals, gaining management support and forming a project team (EPA, 1988; UNEP, 1991).

To start the project, the scope and focus of the study needed to be established, and the project team assembled. The thesis was launched by the authors being provided with an initial broad problem description, describing the need to investigate and improve the company’s paper waste situation at large. However, the scope of the problem was broad and needed to be narrowed down. Through reviewing literature and internal company documents, conducting semi-structured interviews, internal facility walkthroughs and consultations with both the company supervisor and the university supervisor, the complexity and size of the task and production system was understood. These insights made it possible to narrow down the scope of the project and select an appropriate focus. The refined scope was set to solely include two main areas of the production site, and the refined aim to map, quantify and investigate causes for paper waste in these areas. The purpose, problem formulation, research questions and the limitations of the project could therefore be formulated and set. It was also determined that the two authors, under the supervision of the company head of quality and with the help of site employees, would constitute the core project team conducting the study. The goal of the project was set to include an increased understanding of the current state in terms of quantifying waste streams, and to gain insights into problem and potential improvement areas within the production process.

The thesis was initiated by the head of quality and environment in collaboration with the CEO in an attempt to understand why such large quantities of paper were being wasted each year, and if something could be done about it. The importance of these questions had also gained support and commitment from top management and employees with the company before the project launch. Thus sufficient management support had already been established in the beginning of the project, thereby creating a good foundation for the project. As previously mentioned, gaining management support is a prerequisite for successful waste audits (EPA, 1988; UNEP, 1991)

Phase II: Assessing the current state and identifying improvements
The next part of the research process was predominantly based on the main features of the assessment phase in waste audit frameworks. The purpose of the assessment phase, as mentioned above, is to get a detailed understanding of facility operations and waste streams, and to identify and screen waste minimization options (EPA, 1988). Therefore, making it a suitable approach for answering both research question 1 and 2: *Where in the production process is paper waste generated and what are the main waste types that contribute to the paper waste stream?* and *What are the main causes of paper waste generation at the company?*. The main characteristics and activities of the assessment phase have influenced how data has been collected, organized and analyzed in this phase of the project. Moreover, a selection of the seven quality control tools and the seven management tools as described by Bergman and Klefsjö (2010) have also been applied in order to gather, structure, visualize and analyze data.

In the beginning of the project, and throughout the research process, existing process and facility data has been reviewed. The review included: previously conducted internal studies on reducing paper waste, purchasing records, paper recycling records, production records, process maps, checklists (manuals for production and operating practices), and non-conformance and rework reports.

After an initial review of internal records and documents, a facility walkthrough was conducted so that a true picture of the manufacturing process could be obtained, and not solely be based on information found in the business system. The walkthrough followed the material flow through the facility, from paper delivery to the finial shipping of products. By asking questions to production staff members the process steps were further explained and information on actual operating and handoff procedures, paper waste streams and categories were collected. Furthermore, potential causes of waste stream and operators views and attitudes regarding paper waste were also registered. Notes were taken during the walkthrough, which were used in combination with operating manuals/production checklists to create process flow diagrams covering the main production steps. All process maps were verified both by operators and managers knowledgeable of the processes.

The next step was to generate a material balance, i.e. a detailed account of inputs and outputs for target processes, so that waste streams, their composition, and previously unknown material losses could be quantified (Franchetti, 2009; EPA, 1988; UNEP, 1991, Visvanathan, 2007). It was not possible to rely only on existing process and facility data such as production and purchasing records when generating a material balance, instead complementary data needed to be collected. Complementary information was therefore gathered through observations in production, interviews, collecting purchasing and production metrics, and by measuring paper waste in production. This provided a more detailed picture of the paper waste situation and highlighted several areas where information was inaccurate or even missing. Due to missing and inaccurate information a detailed material balance could not be created. Even though a detailed and complete material balance could not be generated, waste minimization options could still be identified within the production process. These options were then evaluated according to the waste minimization hierarchy and other factors such as ease of implementation, which concluded the second phase of the research process.

Phase III: Write thesis and develop recommendations
The third phase of research process focused on documenting the learnings and findings gained during the course of the project, and writing up the report. This so that the case company can acquire the knowledge that have been built during the project and use these insights when continuing the quest of reducing paper waste. Phase three constituted the last part of the project and aimed at answering research question three: *What actions need to be taken by the company in order to reduce current paper waste quantities?*.

3.4 Quality of research

Assessing the quality of research is a somewhat complicated endeavor in a mixed-methods study due to the distinct nature of qualitative and quantitative methods. To ensure a high quality of mixed methods research, both qualitative and quantitative assessment criteria need to be considered. Commonly used assessment criteria for qualitative methods are: credibility, transferability, dependability and confirmability (Bryman and Bell, 2011; Curry and Nunez-Smith, 2015). Each qualitative assessment criterion has an equivalent criterion suitable for evaluating quantitative research (Bryman and Bell, 2011). The four corresponding appraisal criteria for quantitative research are: internal and external validity, reliability and objectivity (Bryman and Bell, 2011; Curry and Nunez-Smith, 2015).

Credibility
The credibility criterion deals with the degree to which the research findings are feasible and cohere with an accepted view of social reality (Bryman and Bell, 2011). In order to achieve a high degree of credibility both respondent validation and triangulation techniques have been applied. Respondent validation entails that findings are submitted to participants of the study

to confirm that they are consistent with their experiences and their view of reality (Bryman and Bell, 2011; Curry and Nunez-Smith, 2015). All process maps have for example been validated by personnel knowledgeable of the process. Triangulation involves the use of different research methods, data sources and theoretical perspectives (Curry and Nunez-Smith, 2015). The technique of triangulation has been used during this research by combining both qualitative and quantitative research methods to see if the different data matches or not.

Transferability

Transferability concerns whether or not the findings can be applied in similar contexts or settings (Curry and Nunez-Smith, 2015). In single case study research the ability to generalize results is however limited (Bryman and Bell, 2011). In qualitative research transferability can be enhanced by providing rich accounts of the study context and details of the studied culture (Bryman and Bell, 2011). The purpose of generating such 'thick descriptions' is to enable readers of the research to evaluate if their own setting is similar to the context of the study, and thus whether the findings hold true for them or not (Curry and Nunez-Smith, 2015). In this thesis, a comprehensive and detailed description of the company's paper waste situation and the research process has been generated. This with the goal to facilitate judgment of the transferability of the report's findings.

Dependability

Dependability reflects to what degree an adequate documentation process has been applied throughout the course of the research (Curry and Nunez-Smith, 2015). Bryman and Bell (2011) argue that good dependability can be obtained by adopting an auditing approach where peers examine the research process and results to evaluate if proper procedures have been followed. The same authors state that an auditing process is enabled by researchers keeping detailed and complete records of all phases of the research process, from conceptualization and problem formulation, to data analysis decisions and interview transcripts. Most records have been kept during the research process, however due to time and other resource constraints external auditing has not been adopted.

Confirmability

Confirmability is concerned with whether the research has been conducted in a neutral and objective manner, without letting personal values or presumptions bias the implementation or interpretation of the study (Curry and Nunez-Smith, 2015). As emphasized by Bryman and Bell (2011) complete objectivity is however impossible to achieve and therefore research should be conducted in 'good faith'. Despite little prior experience of the printing industry and waste reduction initiatives, the authors' experience of other industries, opinions and previous knowledge may have influenced the outcome of the study. However, throughout the research process, the researchers aimed at keeping an open and objective mindset in order to conduct the study in 'good faith'.

Internal validity

In quantitative methods, internal validity is concerned with whether or not the study measures what it is intended to measure, and whether or not there is congruence between researchers' observations and presented theoretical concepts (Bryman and Bell, 2011; Curry and Nunez-Smith, 2015). In this thesis the aim to uphold a high degree of internal validity was done through questioning and verifying the accuracy and quality of gathered quantitative data, both secondary and primary. The data was therefore triangulated with both other quantitative and qualitative data sources. In several occasions this led to secondary data being discarded as the internal validity was deemed to low and thereby not able to reflect reality well.

External validity

External validity parallels transferability and refers to what degree the findings from a study can be generalized across other social settings or populations (Bryman and Bell, 2011). This criterion can be enhanced through random selection, clear definitions and rationale of inclusion/exclusion criteria, and thorough descriptions of statistical procedures (Curry and Nunez-Smith, 2015). In order to make the results from the measurement period applicable beyond the specific period, the researches tried to identify weeks which represented normal production conditions and to make sure that different sources of natural variation of the process were present. Moreover, the execution and setting of the measurement period is described which further allows the reader to evaluate the generalizability of the findings.

Reliability

The criterion of reliability concerns the consistency, stability and repeatability of measurements and observations in quantitative methods (Curry and Nunez-Smith, 2015). Reliability assesses to what extent the measure can be repeated with the same or different participants and obtain the same results (Curry and Nunez-Smith, 2015). It is possible to repeat the measurement period, however the result could differ from the ones obtained in this study, due to the inherent variability of the production process. Furthermore, the reliability of the measurement results can also be questioned as the scale used during the measurement period was discovered to be imprecise. This may therefore have affected the results to a great extent. However actions to assess and assure the reliability of the collected data was handled through triangulation, see chapter 4.5.3. By explaining and describing research procedures and data collection methods in detail the aim is to make the study repeatable to others.

Objectivity

Objectivity is paralleled by confirmability in qualitative research and addresses the degree to which researchers can remain neutral and let findings reflect the nature of what is studied rather than personal beliefs, agendas or other biases (Curry and Nunez-Smith, 2015). Because of its similarity to confirmability, achieving a high degree of objectivity has been strived for by conducting the study in 'good faith'.

3.5 Ethics

During the course of the project there are several ethical principles that need to be considered; participant harm, lack of informed consent, privacy invasion and deception (Diener and Crandall, 1978). To avoid the study from potentially inflicting harm to the participants, interviewees have been kept anonymous and the gathered information has been presented in an aggregated manner. However, due to the specific nature of certain information, there is a possibility that some data can be tied directly to an individual. Furthermore, all interviewees were verbally informed about the purpose of the study and the specific goal of the interview, and in the cases where interviews were recorded, permission to do so was always asked beforehand. Moreover, all observations have been conducted in an overt manner, and the purpose of the observations presented beforehand. Thus there has been no intentional deception present. Therefore, it is assumed that the ethical criteria have been adequately considered in this study.

Since the researchers have spent extensive parts of the project on-site the company's views and opinions might have affected the researchers mindsets and thereby the analysis and results of the study. However, to avoid this, the researchers conducted most of the analyses off-site in order to keep an open mindset and to present and discuss the results of the study honestly and without preconceptions.

4. Results of the empirical study

Information collected from literature, interviews, observations, measurements and secondary data are presented in this chapter. It begins with a short presentation of the case study company and continues with a more detailed description of production procedures and operating practices. Then identified deficiencies of current reporting practices are presented and lastly the quantification of paper waste is discussed. Paragraphs without direct references should be seen as results from observations and interviews made by the authors throughout the project, as this is in alignment with the ethical considerations of this study.

4.1 Company presentation

The case company employs around 300 people and currently operates at several production sites in Sweden. The company operates within the graphic industry and tends to customers' packaging and printed product needs by combining graphic products with additional services such as kitting, packing and just-in-time delivery. The company is certified in the quality management system standard ISO 9001, as well as in the environmental management standard ISO 14001. Among other things this entails that organizational policies and goals exist, that guidelines for work processes are put in place, and that deviations and improvement opportunities are acknowledged and managed. The production sites are also climate neutral. The company's organization chart can be seen in figure 6 below. The main site handles offset printing, fulfillment, packaging, prepress and bindery operations, while digital printing activities are concentrated to other sites. Since this study has been focused on the offset, bindery and logistics operations, digital printing along with fulfillment and packaging functions will not be further discussed.

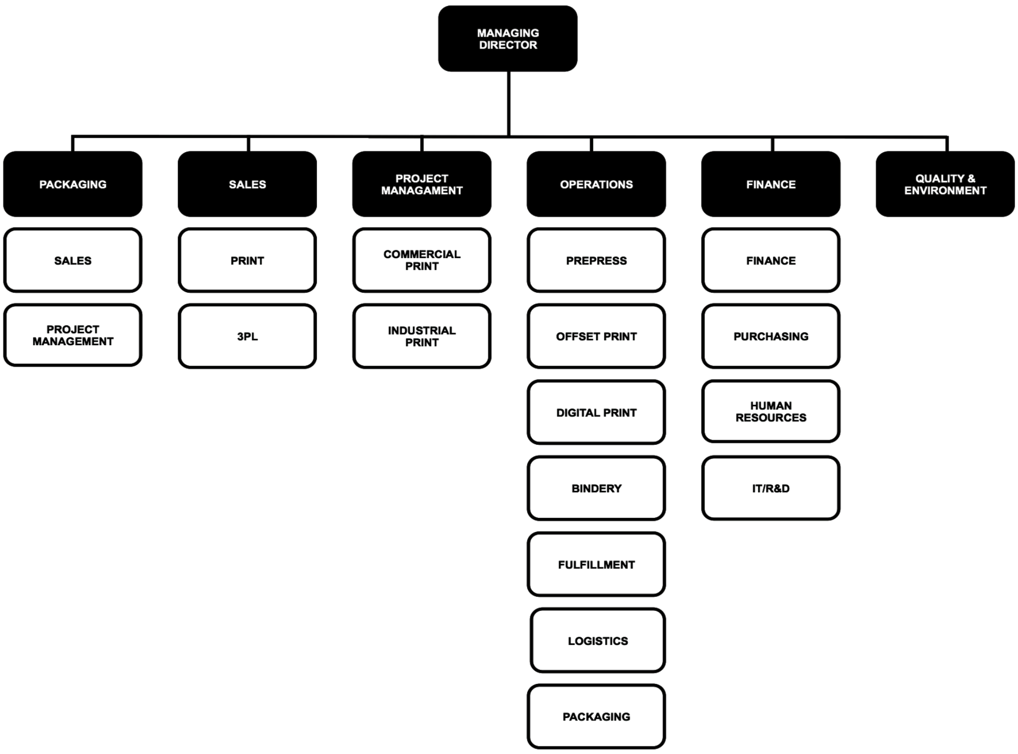

Figure 6. The company's organizational chart

4.2 Current waste management practices

In this section the company's current waste management practices at the investigated production site are described. First a short description of previously conducted paper waste projects will be presented. Then a description of how the company measures and monitors paper waste levels at present will be described, and lastly the operational logistics of the company's waste management practices will be presented.

Two previous projects with the aim of reducing paper waste levels have been conducted at the company during the past few years. In the spring of 2005 a small university thesis was written on the topic, however the work did not lead to any substantial changes. The second project conducted a few years ago consisted of a number of brainstorming sessions with key personnel, and resulted in the reduction of paper waste in the digital printing department at the investigated site. However, it was also concluded that improvements in the offset production process and the bindery are difficult to realize and therefore no actions were taken within these departments. Since then no further paper waste minimization projects have been started.

To monitor paper waste levels the company has established the performance indicator (PI) 'Paper waste'. The PI puts the amount of paper retrieved by their recycling partner in relation to the amount of purchased paper on a month-by-month basis, as previously mentioned. See equation 1 for the calculation of the PI.

Equation 1. Paper waste

$$Paper\ waste\ (\%) = \frac{Paper\ waste\ (kg)}{Purchased\ paper\ (kg)} \times 100$$

The PI provides an estimate on how much paper waste the company generates each month, see table 4 for results during 2015. Unfortunately the measurements are not able to fully reflect a month's actual performance, due to inherent noise in input data. The calculation is based on the amount of recycled paper during one month, and not the actual paper waste generated during that month. Moreover, the purchased quantity of paper during a month does not fully reflect the quantity of paper actually utilized in production during that month. Therefore, in both the case of the denominator and the numerator, the PI can include data from previous months and exclude data from the month the PI is intended to measure. Due to this, variations between months can be amplified or lessened, and true differences between months left undisplayed. Furthermore, order factors can influence variations between months, as paper waste percentages can differ significantly between different orders. For example, in the offset production process make-ready sheets are required for all printing jobs, however the number of sheets needed is not directly correlated to the size of the order. Setting up the printing press for a small and a large order may require the same amount of make-ready sheets, making the percentages of paper waste between the orders significantly different. Therefore, a month's order mix can also be the cause of variations between months. The PI itself is therefore not able to suggest if variations between months is the result of good production conditions or other variables. Deeper analyses of production conditions are therefore required in order to draw conclusions from the measure. Currently, there are no such analyzes conducted to find causes for fluctuations between months. If differences between months are due to noise in input data or caused by other reasons is therefore unknown. Due to this the average generated during several months is used to assess the efficiency of raw material consumption at present. The PI is consequently only used to follow paper waste developments on a high level.

Table 4. Paper waste levels from January 2015 until November 2015.

	Jan.	Feb.	Mar.	Apr.	May	June	July*	Aug.	Sept.	Oct.	Nov.	Avg.
Paper waste (%)	33,6	33,0	32,4	43,5	50,5	38,9	19,4	36,8	33,1	35,9	38,2	35,4

*The low outcome in July is a result of low production volumes due to summer vacations.

Operators and logistics personnel are responsible for the collection and transportation of wastes. Waste containers have been strategically placed throughout the production process in order to collect and separate waste streams. Operators are responsible for the collection and separation of different types of wastes within the production process. Meanwhile the logistics personnel are responsible for emptying the waste containers when full. The waste containers are emptied into processing equipment for volume reductions and/or into larger containers for storage, before the recycling partner retrieves the waste. In some cases the processing equipment, except for reducing volumes, also stores the waste. The use of processing equipment has reduced the number of transports needed to the recycling partner and made it possible to store larger amounts of waste at the facility. Furthermore, a tailored waste extraction system has been installed throughout the production facility in order to manage paper trimmings and dust generated in the production process. The system consists of a pipeline that transports cutting waste and paper dust from machines within the bindery to a material separator, which separates the dust from the solid material. Then the dust-free paper is compacted into a container and the dust is pressed into briquettes. The separation of paper dust from the solid paper waste is an important aspect of the waste extraction system, since solid paper can be recycled while paper dust cannot, therefore the recyclability of waste is increased by the system. Paper dust briquettes are mixed in with other types of combustible wastes and not measured separately, thereby making its quantity unknown at present and therefore excluded from paper waste calculations. The company's recycling partner handles off-site transportation, recycling, recovery, and disposal of wastes. The company receives revenues from the sales of paper due to its recyclability, while the external handling of other waste streams generates a cost.

4.3 Main operations influencing paper waste

In this section the main operations and processes influencing paper waste will be described, and sources and causes of waste identified. First paper procurement, inventory management practices and material handling procedures will be presented, followed by a description of the current production process and its integral parts.

4.3.1 Paper purchasing, inventory management and material handling

How paper is purchased, inventory managed and material handled affects the generation of paper waste, especially in the form of surplus paper from production runs as this has a tendency to be discarded. The logistics department is responsible for incoming material deliveries and the handling of paper. When paper is delivered the logistics personnel unload the goods and visually examines the shipment for defects and transport damages. If defects are identified, the vendor is contacted and the goods returned. Paper that passes the visual quality control is transported into the facility and stored until it is to be used in production. Internal transports and storage handling procedures can damage paper and generate waste, this is however not common and thereby not a source that generates substantial paper waste amounts. Instead the largest source of paper waste in terms of handling procedures is connected to how surplus quantities from production runs are managed.

Surplus quantities of paper from offset printing runs are common, and a natural outcome of the current production system. First of all it is difficult to anticipate exactly how many sheets of paper an order will require. It depends on a combination of order-specific factors such as paper quality, color specification, and number of printing plates; and non order-specific factors such as experience of the printing operator and machine settings. Generous estimations leads to an increased handling of paper while too sparse estimations can lead to paper shortage. When the amount of paper intended for an order is not enough to complete the print and more paper is needed, the same quality of paper is directly brought to the press if available, which may include borrowing paper specified for another order. In other instances finishing the order may require additional paper to be delivered from the vendor, in which case the remainder of the job is postponed. As it is very expensive to interrupt the offset printing process, underestimations are more severe than overestimations, which have resulted in surplus paper from production runs being common. Unfortunately, it is difficult to quantitatively analyze how well the estimations of gross number of sheets match with the actual production quantity needed, because the consumption of paper is not sufficiently reported. However, due to the complexity of paper quantity estimations and the instability of the production process, surplus paper is expected and therefore needs to be managed in a more efficient way.

Current purchasing conditions and terms also affects surplus quantities. At present, four vendors supply the majority of purchased paper to the company, the biggest of which supplied over 75 percent of total paper quantities during 2015. The company maintains a close relationship with its largest supplier, which has resulted in the development of a Vendor Managed Inventory (VMI) system, through which most activities regarding paper stock replenishment are managed. The VMI-system is suppose to enable that a wide range of paper qualities can be offered to customers without keeping a large inventory, as it incorporates an on-demand solution in combination with a good return policy. The VMI-system also reduces the administrative burden of the operational buyer. Paper is delivered two times a day with the VMI solution; one time in the morning, and once in the afternoon. The morning delivery contains paper to cover production needs from midday to midnight, and the afternoon delivery covers paper needs from midnight to midday the following day. The vendor bases its deliveries on the production schedule, and supplies each production order with the number of gross paper sheets calculated for it, which makes delivered quantities order-specific. Therefore, for the VMI-system to operate efficiently the number of gross sheets calculated for an order needs to be a good estimate of the quantity actually used. The paper needs for the morning delivery are extracted from the production schedule at 2 p.m. the day before the delivery, and at 9 a.m. the same day, for the afternoon delivery. In theory the exact amount of paper needed in production for the coming twelfth hours is supposed to be delivered from the vendor to the site. If there is surplus paper from a produced order, it is supposed to be returned to the vendor if possible, so that the need to store paper in-house is reduced.

The VMI solution does however not always work quite as smoothly as intended. The solution's ability to efficiently supply paper to production at a given time is largely affected by last-minute changes in production planning. Changes are quite common and can include rescheduling orders and altering orders' paper requirements. Late changes to the production schedule can result in delivered quantities and qualities of paper not corresponding to the paper needed in production. Sometimes order-specific paper is not in stock for one order, and paper specified for another order is used to cover the shortage. This can lead to acute paper shortages, which sometimes are solved through costly last-minute procurement arrangements. In other instances, order-specific paper has been delivered but the production of the order has been postponed, requiring the paper to be stored. When the order is finally printed, surplus paper from previously produced orders may be available, making some of the order-specific paper excessive.

Last-minute changes to the production schedule counteract the underlying rationale and potential benefits of the VMI-system, as they result in discrepancies between needed paper and available paper in production. In turn these discrepancies lead to increased complexity for the purchasing function, excessive handling of paper and to suboptimal use of valuable storage capacity. Furthermore, the VMI-system does not consider inventory levels and continuously provides a steady supply of paper for upcoming orders. This results in surplus paper being stored longer than necessary, which affects inventory turnover and available storage space. Uncoupled systems also obstructs efficient inventory management as the operational buyer has to manually check inventory levels and cancel planned VMI-deliveries if stored paper is to be used.

From all other suppliers paper is manually ordered based on current inventory levels and the aggregated need in production. Whole pallets or packages need to be ordered from these suppliers and results in larger quantities than needed being bought. As returns are only accepted for unbroken pallets or packages from these suppliers, the excessive quantity needs to be stockpiled, and commonly leads to surplus paper.

The logistics personnel are responsible for the handling of surplus paper, and the supply of paper to the production process. When an order is to be printed, the appropriate paper is placed adjacent to the offset printing press. The quantity of paper placed by the press is usually more than sufficient to print a job and commonly results in surplus paper. Surplus paper is supposed to be handed back to the logistics department, and is then either returned to the vendor, stored or scrapped, see figure 7. If paper cannot be returned to the supplier, a decision of whether to scrap or store the paper needs to be made. This process is at present very ad-hoc and depends on several factors such as the quantity, quality, cost of paper, planned future consumption and storage availability. The current stock levels are however seldom taken into account in the decision process and results in surplus quantities, which could have been stored, being scrapped.

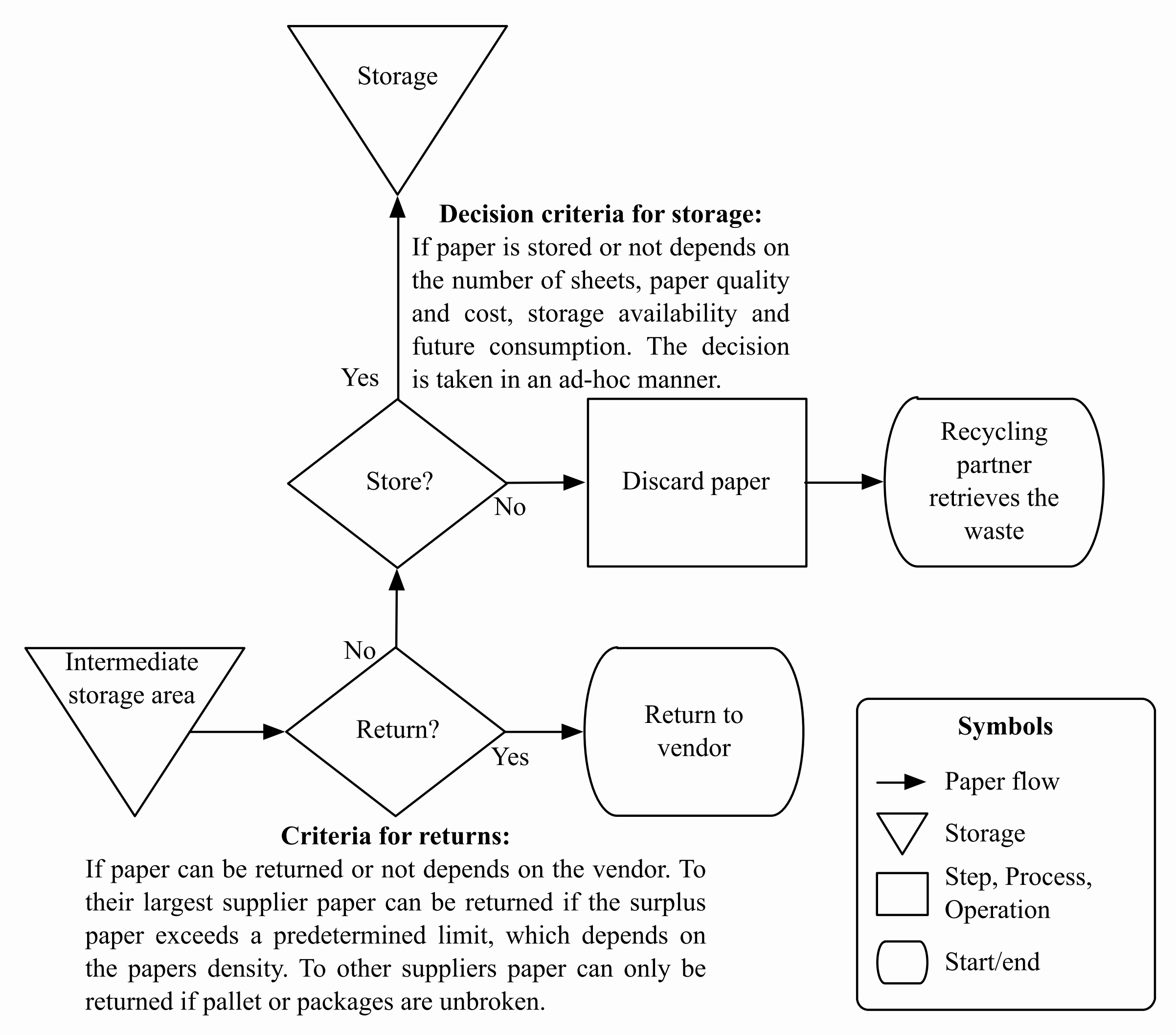

Figure 7. Decision-making process for surplus paper.

The large variety of paper quantities used in combination with low inventory capacity and inaccurate inventory figures leads to large amounts of unused paper being scrapped. However if the accuracy of inventory figures were increased, it would be possible to make more informed decisions on how surplus paper can be managed. If the paper quality is stocked there might be a possibility to increase that quantity or even return the paper to the vendor if the two quantities are combined, instead of scrapping the paper. Furthermore, surplus paper quantities are discarded due to inefficient inventory practices. For example VMI-orders have to be manually canceled if stored paper is to be used as the VMI-system and inventory figures lacks synchronization. However, as inventory levels are inaccurate this rarely happens and therefore paper quantities can be stocked for longer periods than necessary and take up valuable space and drive up costs. Consequently, unreliable inventory figures affects inventory control and makes it difficult to make informed decisions regarding surplus paper.

At present, the operational buyer, the printing operators and the logistics personnel alter inventory levels. The operational buyer reports the incoming material, and as mentioned previously, regularly makes manual adjustments to the best of his ability to increase the accuracy of inventory figures. The reported amount of sheets, if reported at all, most commonly equals the number of imprints made during a production run. Therefore, discarded paper at the feeding unit is seldom accounted for and therefore not removed from stock levels. Furthermore, the logistics personnel often miss to report returned, stored or scrapped material, which further decreases the reliability of the figures. Therefore, both paper, which is registered, to be in stock can actually be missing and vice versa.

The large variety of paper qualities in combination with the current VMI-solution has made the procurement and management of paper difficult. In the beginning of 2016 a pilot project was therefore initiated aimed at decreasing paper handling and costs associated with order specific paper. For the project, two of the most common paper qualities were moved out of the VMI-solution and are instead manually ordered in larger quantities than before. Ordering in bulk decreases required transports and eliminates the need to handle order-specific quantities on individual pallets. The project is a step in assessing if the introduction of standard "in-house" paper qualities that would be stocked at all times would be beneficial. Introducing standard qualities would entail moving the most common qualities used in production out of the VMI-solution and instead manually ordering these with the help of an order point system. The ability to offer a wide range of paper qualities to customers is largely facilitated by the VMI-system and therefore only the most common qualities would be excluded from the system if the trial period proves to be beneficial. However, hopes are that the introduction of standard paper qualities will help decrease the large number of paper qualities currently used, through the introduction of appropriate internal promotion guidelines and by providing customers with incentives to choose the standard qualities. Such a solution could lead to less surplus paper being scrapped as standard qualities would have dedicated storage space which would facilitate the storage of surplus paper.

4.3.2 Production process

When an order is received at the plant, the first step of the production process is preparing the order file for printing, which is done by the prepress function. Prepress makes sure that files are properly processed in preparation for printing, and is responsible for all activities that occur between the creation of a print layout and final printing. Activities include editing and proofing documents and pictures, generating high resolution PDF-files, imposition, and creating printing plates for offset printing. The printing plates are then delivered to the sheet fed offset printing function where the print is transferred onto paper. When a job has been printed the paper sheets usually undergo post-printing operations in the bindery function. This may include trimming, punching, creasing, folding and binding depending on type of product and customer preference. Punching and creasing have been excluded from the focus of this study as the operations are seldom performed and therefore their contribution to paper waste is in-significant. The main steps of a generic offset production process are visualized in figure 8 below.

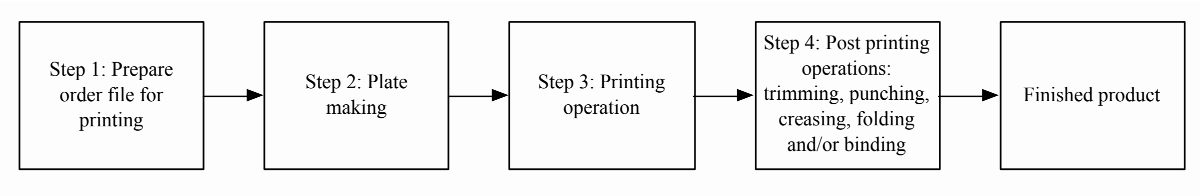

Figure 8. Generic offset printing process.

This study has however only focused on the offset printing process and the post printing operations conducted in the bindery along with operations supporting these processes such as paper handling, supply and procurement. Activities performed in prepress affects the ensuing operations and may cause paper waste to be generated in other functions, but prepress generates no paper waste itself. Therefore prepress activities are considered only in terms of how they affect other functions' generation of paper waste, but they will not be described below. Figure 9 below displays the production layout at the investigated site and main operations explored in this study.

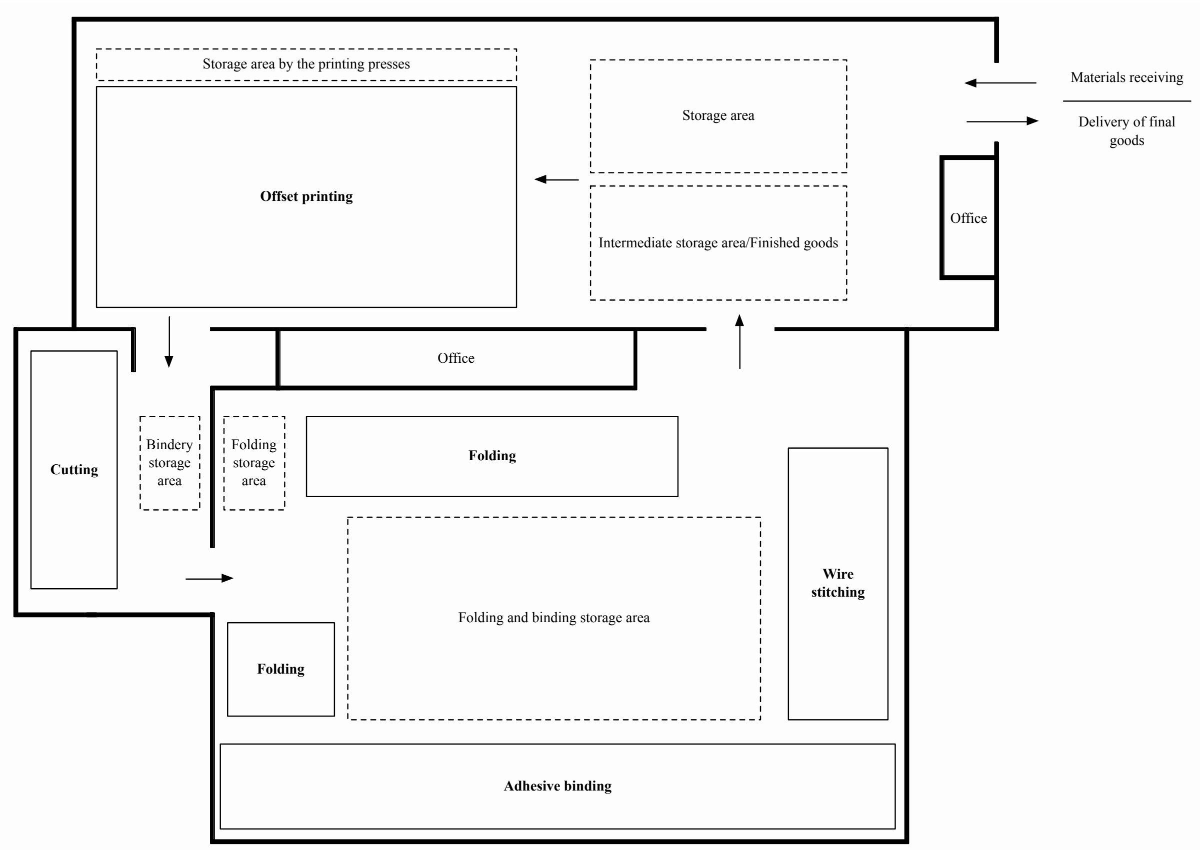

Figure 9. Production layout

Quality control routines

Quality control routines have been implemented throughout the production process in order to assure a high quality of produced products. However, defective products can still be produced and slip through the production process, and generate large costs and paper waste. After paper has been processed the production process is irreversible, thereby the production process needs to be repeated and faulty products discarded if defects are found. Defects can include, to name a few, faulty impositions, color variations between the different sheets, wrongly cut or folded sheets, smeared printings and scratches in printing plates leading to a low quality of print. Identified faults result in non-conformance reports, which are followed up on a regular basis at the company. Investigating the causes of reported faults and suggesting and implementing measures to assure process quality is an ongoing process at the company. Since there are routines put in place to handle non-conformances in production, and as an initial assessment of deviation compilations and reports showed that investigating causes and generating improvement ideas regarding non-conformances would require a substantial amount of work, it was decided that they would be excluded from this study. Therefore the causes of reported non-conformances and their effects on paper waste quantities have not been explored. Quality control routines will however still be broadly described in the report as they increase the understanding of paper waste generation at the company.

Offset printing

Sheet fed offset printing is the most widespread printing technique and is used for printing products ranging from simple flyers, folders, brochures, annual reports and exclusive books to packaging material (Johansson et al., 2006). Offset is an indirect printing technique in which the colored image is transferred from a printing plate on to the material which is to be printed (normally paper), via a rubber blanket. The production site currently holds four offset printing presses: two presses (708A and 708B) with eight printing units each, which are able to print four colors on both sides of a paper sheet in one run; one press (705) with five printing units, which is able to print four colors plus lacquer on one side in one run; and one press (704) with four printing units, which is able to print four colors on one side, or two colors on both sides in one run.

Offset production is a complex and variable process that is affected by many different factors. Job characteristics, printing press settings, paper conditions, operator experience and skill among many other things affects the quality of a printed job and the efficiency of the printing process. In the offset production process paper waste can be generated due to a multitude of reasons and stem from a variety of sources, and some of it is seen as a natural part of the process. Before an order is printed, the printing press needs to be prepared. Preparations are done by the press operator and include installing the printing plates into the press, inking the press, configuring press settings and loading the press with paper. For a job to run smoothly, preparation activities are repeated throughout the printing process whenever needed. To avoid running into problems when the job has started and to assure sufficient quality of the print throughout the printing process make-ready sheets are printed and examined. Make-ready sheets are used to ensure that the press is printing properly, that ink and color proportions are correct, and that the overall design of the print is as intended. The time and effort required to set up the printing presses as well as the number of make-ready sheets varies between jobs. For instance, setting up jobs containing many colors and pictures is different from the setup required for black and white jobs with only text, which in combination with the skill and experience of the process operator causes variations in time and resources needed for setup.

Make-ready sheets are considered to be a necessary source of paper waste and therefore little is done to reduce these quantities today, despite the fact that they make up a considerable amount of the offset production's paper waste.

The characteristics and conditions of input paper can greatly affect the efficiency of the offset printing process and lead to paper waste. The quality of paper can be altered due to storage aspects such as temperature and humidity, but also due other factors such as wrapping and transports. Factors such as rips, wrinkles, folded corners, rounded edges, moisture and thickness of paper can have a great affect on the print quality or the machine's performance. For example paper may not feed through the machine, feed at an angle or wrinkle during the printing process. Resulting in for example paper jams, skewed printed products or the creation of creases in sheets. Therefore, before paper is placed in the feeder system a visual inspection is conducted by the printers and defect paper discarded. The top and bottom layer on pallets are always thrown away, as these sheets often are damaged from transports and packaging in some way. Damaged paper scrapped due to transport and packaging is a natural outcome of how paper is shipped at present. However the amount of paper appropriate to discard is decided by the press operator in an arbitrary way, leading to that usable paper ends up as waste. Furthermore, when there is surplus paper left from the production of an order operators may choose to discard this as well even if it is of good quality. Because printers are aware that small quantities of paper probably will be thrown away by the logistics department at a later stage anyways, as previously described. Sometimes printers therefore chose to discard the paper themselves instead of returning it to the logistics personnel, as the outcome for the paper probably would be the same.

Inadequately or faulty printed sheets due to errors from offset production or previous operations, can be detected and generate paper waste within the offset printing process. However, faulty or defective products may also slip through to the following operations. Inadequately printed sheets can stem from a multitude of reasons such as machine malfunctions or input material problems, which can lead to for example smeared printings or creases in printed sheets. Other errors leading to paper waste can stem from previous operations and be the result of for example faulty imposition or scratched printing plates.

Paper waste types generated within the offset production process are consequently: make-ready sheets, damaged or usable paper discarded from the quality control of input material, surplus paper, damaged paper from paper jams, and insufficient or faulty printed sheets. However, as make-ready sheets, paper discarded from input material controls and paper surpluses from production runs constitute the majority of the total quantity of waste generated from the printing process other sources will not be further investigated in this section. For the offset production process and its connected paper waste types, see figure 10.

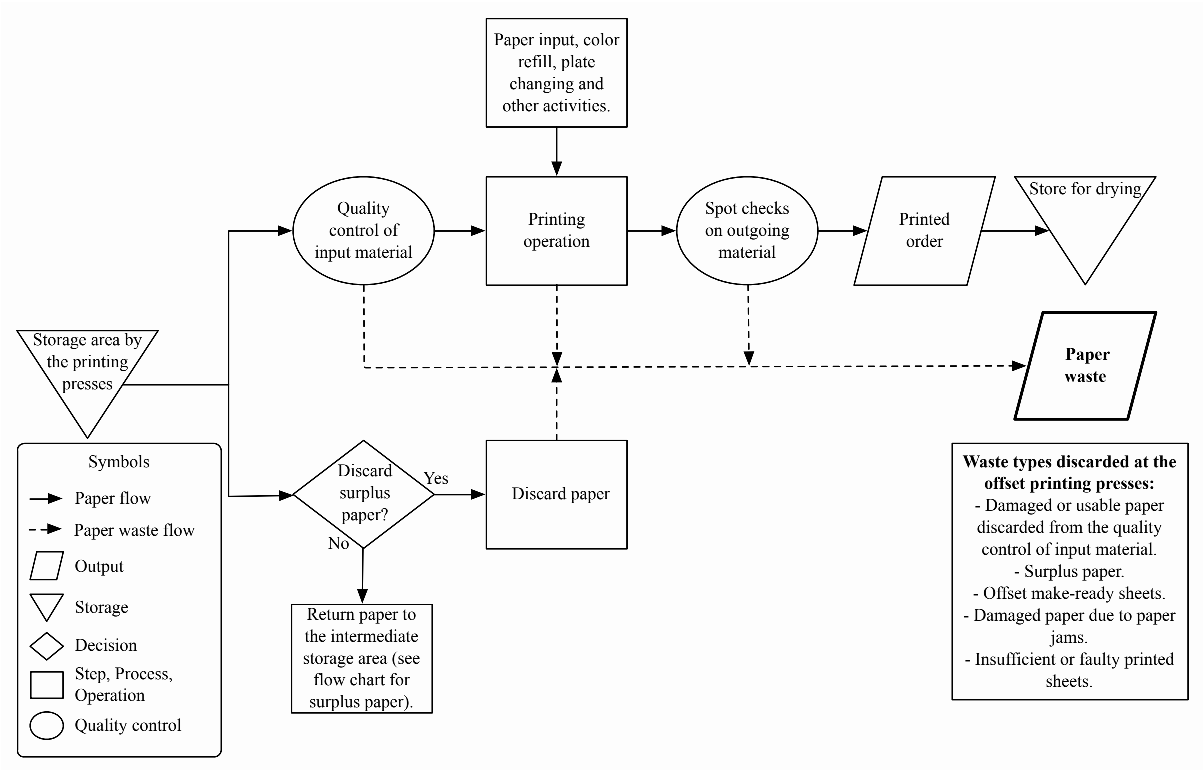

Figure 10. Process chart for Offset printing

Make-ready sheets are a necessary part of the printing process in order to achieve a high quality of print, and constitute the largest source of paper waste in the offset printing process under normal operating conditions. Figure 11 displays make-ready imprints as percentage of total imprints per week and press for fifteen consecutive weeks, from the automatically generated figures from the printing presses.

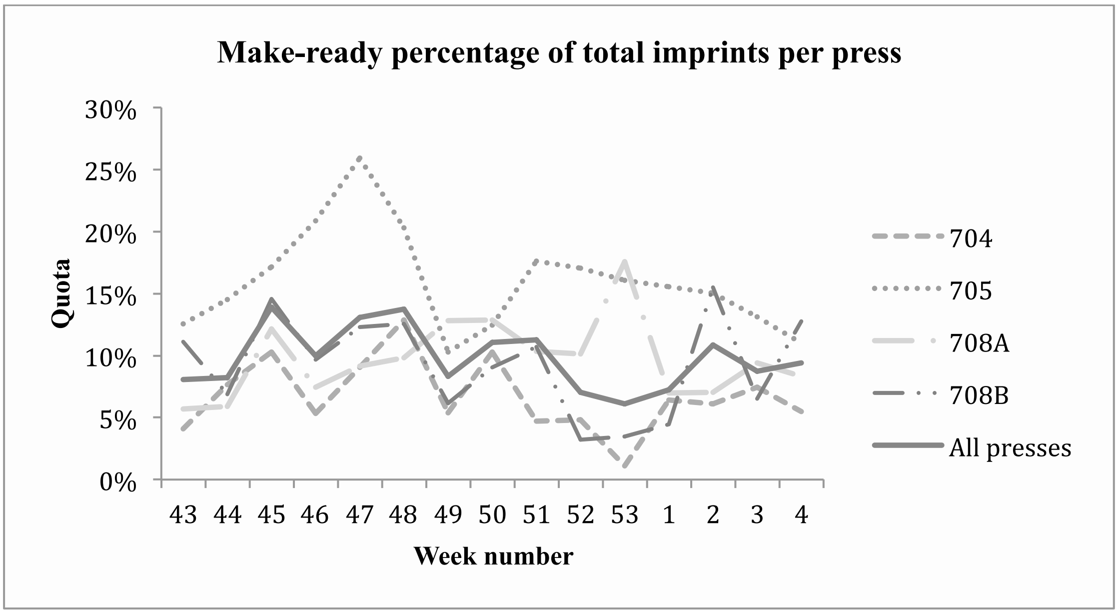

Figure 11. Make-ready percentages of total imprints per press for 15 consecutive weeks

As can be seen in figure 11, make-ready percentages fluctuate between weeks for all presses, the exact cause of the fluctuations are difficult to assess as many factors influence the output. Make-ready quantities are affected by several factors; printer experience and skill, characteristics and conditions of input paper, previous press settings, maintenance and service procedures, and difficulty of print. Furthermore, for some jobs the customer itself examines the make-ready sheets to ensure satisfactory quality of the print. This commonly entails more adjustments and make-ready sheets than if the operator had prepared the job and machine himself. However, at present a large cause for paper waste generation seems to be connected to the present mindset and attitude towards paper consumption. The mindset and attitudes towards paper consumptions expressed, by both operators and other employees, points to that reducing paper waste quantities is not highly prioritized, which affects not only make-ready quantities but also surplus paper and usable paper discarded from input quality controls. The main concerns during the printing process is to get the job done right and on time, which is understandable as the offset production process is the single largest expense of the production process. The priority is therefore to keep the presses up and running, and paper consumption consequently becomes secondary. Furthermore, as practices to take care of surplus paper are deficient, incentives to reduce the number of make-ready sheets used are lacking for print operators. The view is that gross amount of sheets calculated for an order are "supposed" to be used, and decreasing make-ready sheets or other types of waste might only lead to them being discarded anyways due to deficient paper handling practices. It can therefore be hard to motivate printers to decrease the amount of paper used during the production of an order.

Cutting

Almost all printed jobs need to be cut or trimmed in order to arrive at their intended formats. The majority of these operations are performed at the cutting function which consists of two guillotine cutting machines. Operations may include separating multiple copies of an image printed on the same sheet, separating signature pages, and trimming excess paper off the edges. Paper waste is a natural byproduct of modifying the printed sheet into the desired format and something that the operators in this function are not able to influence to any significant extent. During the two-week measurement period in production, the utilization degrees of sheets ranged from 24 to 95 percentages between the printed jobs, with an average of 84 and a median of 77 percentages.

It is possible for the operator to cut the sheet in a faulty way rendering it useless, but this rarely happens (8 non-conformance reports were connected to faulty cutting during 2015). Instead how much paper is cut away depends largely on the imposition of images and texts on the sheet and on the format of the sheet versus the final product format. The cutting waste can thus be seen as a result of the design of the product and the current production setup. Make-ready sheets from offset printing can also be discarded at the cutting station, as these often constitute the bottom layers on pallets of printed sheets. Types of paper waste discarded at the cutting stations include trimmings (including paper dust), wrongly cut sheets and make-ready sheets from the offset printing process. Furthermore, other errors such as faulty imposition or insufficiently printed sheets can also be discovered during the two quality controls present within the cutting process, and therefore be discarded at the cutting station. First a visual quality control of input material is conducted in order to detect faulty products. The operator's ability to visually detect flaws is largely dependent on his/her knowledge of the work order and on previous experience. During cutting operations random samples are inspected to assure that the quality is satisfactory, which includes test-folding products and/or visual assessments. For waste types and process map for cutting, see figure 12.

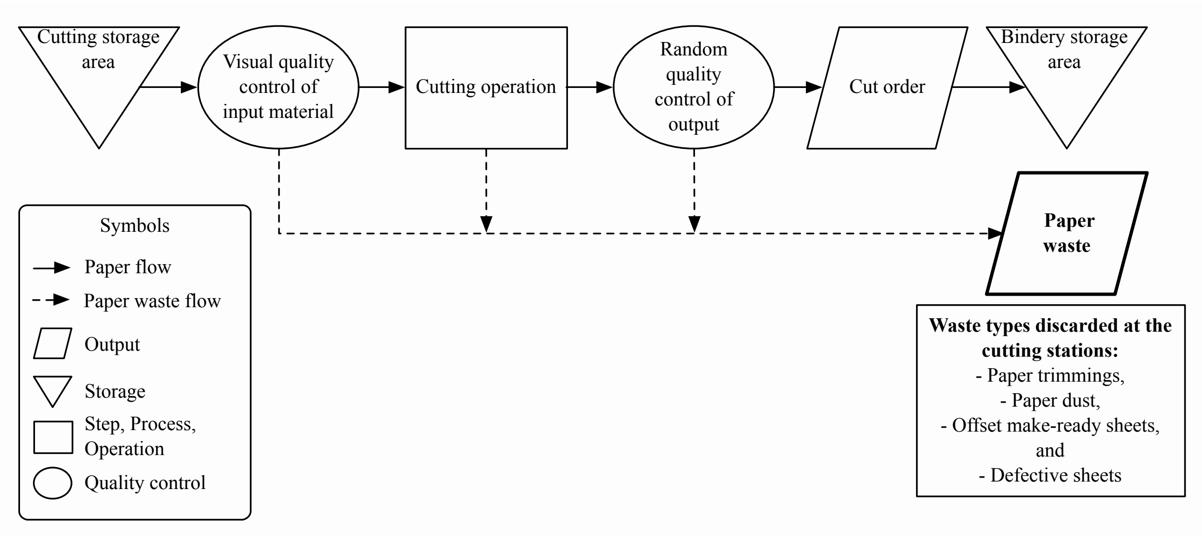

Figure 12. Process map for the cutting department

Folding

Most printed products require some sort of folding to get the arrangement of pages correct. Usually multiple pages are printed onto a large sheet of paper, which is then folded into signatures or folders. The folding is done in an automated fashion in a folding machine. As within offset production, folding operations require setup sheets to prepare production runs. The amounts of setup sheets required for folding are however much lower than the amount required in offset printing: only a couple of dozens compared to a couple of hundred sheets. However, if problems arise during folding operations hundreds of sheets may be scrapped during setup and/or due to paper jams. How paper sheets are stacked on a pallet affects the production rate and the amount of paper waste generated significantly during folding operations. If sheets are unevenly stacked or slightly damaged it influences how paper is fed into or through the folding machine. Paper can for example be fed at an angle or multiple sheets can be fed at the same time, which can result in paper jams or wrongly folded sheets.

At present, sheets of good quality are used during folding setups, which can have a significant effect on the number of finished products. Because if a book is to be bound, the component with the least number of copies will determine the maximum number of finished products that can be made. This does not only affect the amount of produced products but also the amount of paper waste, as is results in redundant signatures and covers that need to be discarded.

There are currently seven folding machines at the company, which are suitable for different types of jobs. However, the amount of sheets scrapped due to setup is believed to be roughly the same for all machines.

Paper waste types generated by the folding units are setup sheets, damaged sheets due to paper jams, and deficient folder or signatures. Deficient folders or signatures can for example entail that printed sheets become smeared or that sheets have been folded wrongly, and is believed to mainly be a result of operators not fully reading work orders. If the final product is a folder overproduction quantities can also be discarded at the folding stations. Other types of paper waste discarded are make-ready sheets from offset printing presses, which arises if products need to be folded but do not require cutting, sheets are therefore brought directly to the folding department from the printing presses. Before paper is fed into a folding machine a visual quality control is conducted so that transport damages and other defective sheets can be discarded. After the folding operation another quality control is conducted where for example pagination, transition images and creasing are checked on the folded products. If errors such as incorrect pagination and or insufficient printed sheets are detected these can also be discarded at the station. For the folding operations process map and waste types, see figure 13.

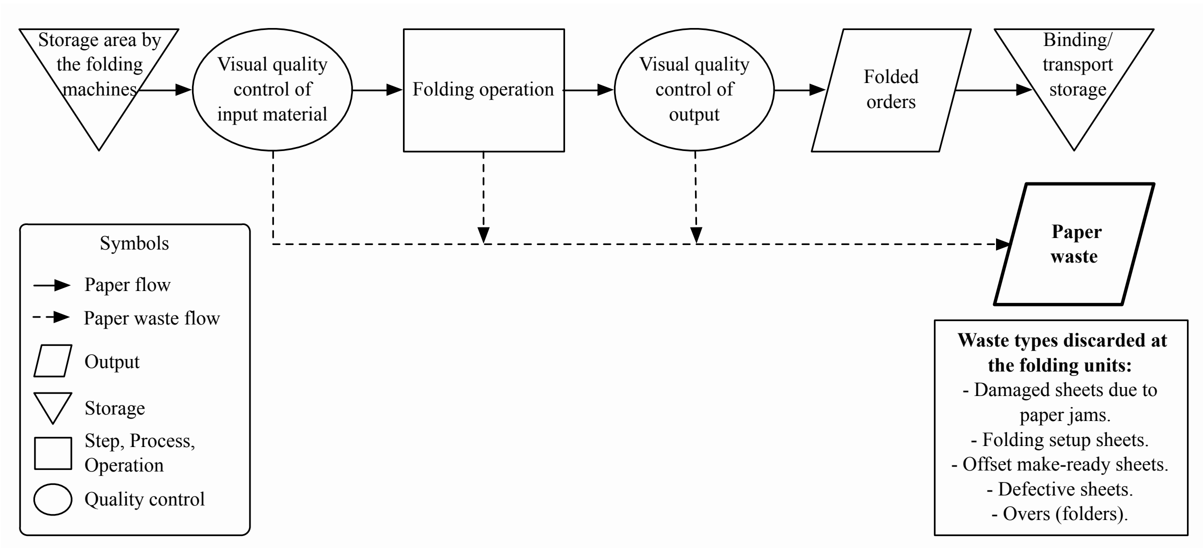

Figure 13. Process map for the folding department

Adhesive binding and wire stitching

Before binding is possible, the folded sheets need to be sequenced correctly, which is done through the process of gathering. Depending on the binding method that will be used, the folded signatures can be gathered in two main ways. When a product is to be bound through wire stitching, signatures are gathered by the insertion of one signature into another one. When a product is to be bound through adhesive binding, signatures are placed next to each other and organized into a set allowing their spines to be glued together.

The two most common binding techniques at the production site are wire stitching and adhesive binding. Wire stitching techniques are used to bind together pages by driving wire staples through them, usually through the center of the spine of the folded sheets, or through the cover and down through the pages. The technique of adhesive binding on the other hand, entails fastening the gathered signatures to a cover by gluing them together. Both binding techniques include manual and automated activities, and are organized in a production line manner centered around specialized machinery.

Paper waste arises at several steps in the adhesive binding process and in different types such as; setup books; cutting waste; overs in the form of books, signatures and covers; and defective products, see figure 14. The first step in the adhesive binding process is a quality control of input material, where signatures and covers are visually checked and compared to order information. The signatures are then manually fed into specific pockets, after which they are automatically gathered together for binding. A second quality control is then performed where the pagination is verified before the binding procedure begins. The spine of the gathered signatures is then milled before glue is added and the cover attached. After this a third quality control is conducted, where book spines are cut open to assess the quality of the binding and if adjustments need to made to the milling or glue unit. Furthermore, the pagination is checked once again. Books are then cut into their intended format by a three-knife trimmer. A final overall quality control is then conducted before the finished products are packaged and transported to the logistics department for delivery.

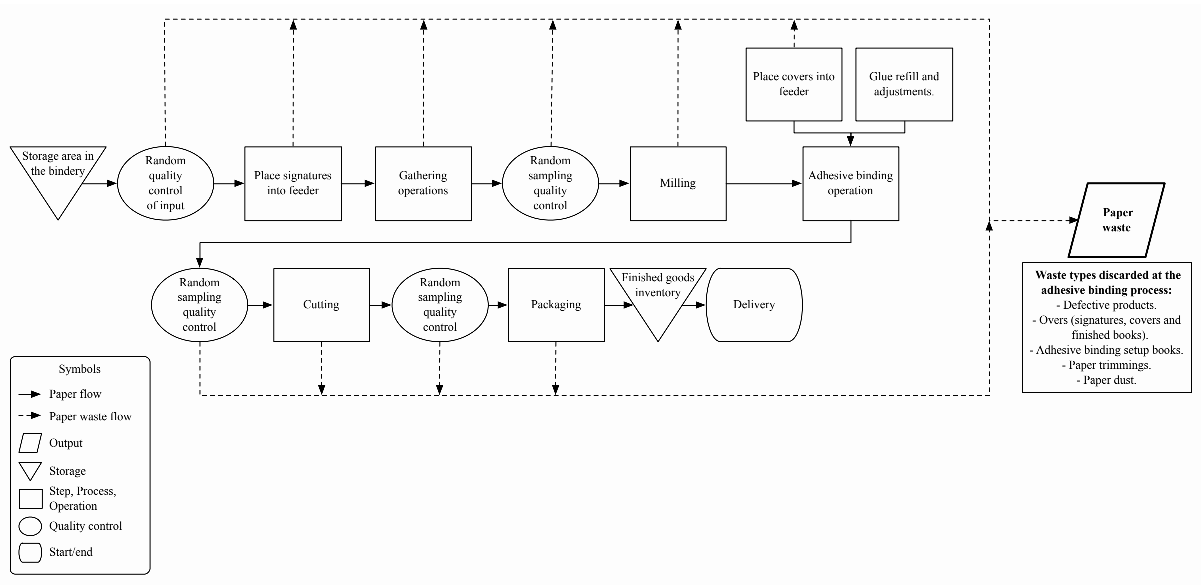

Figure 14. Process map for the Adhesive binding department.

Waste generated within the wire stitching station shares several commonalities with the paper waste generated at the adhesive binding operation, waste is also generated due to overproduction, cutting operations, setup operations and defectively produced products, see figure 15 for process map and waste types. The process starts with a quality control of input material, the covers and signatures are then manually placed into specific pockets before they are automatically gathered together for binding. A second quality control is then conducted, where for example the pagination and cover placement is checked. The unbound books are then automatically stitched together and cut into the right format by a three knife trimmer. A last quality control is then conducted before the books are packaged and transported to the logistics department for customer delivery.

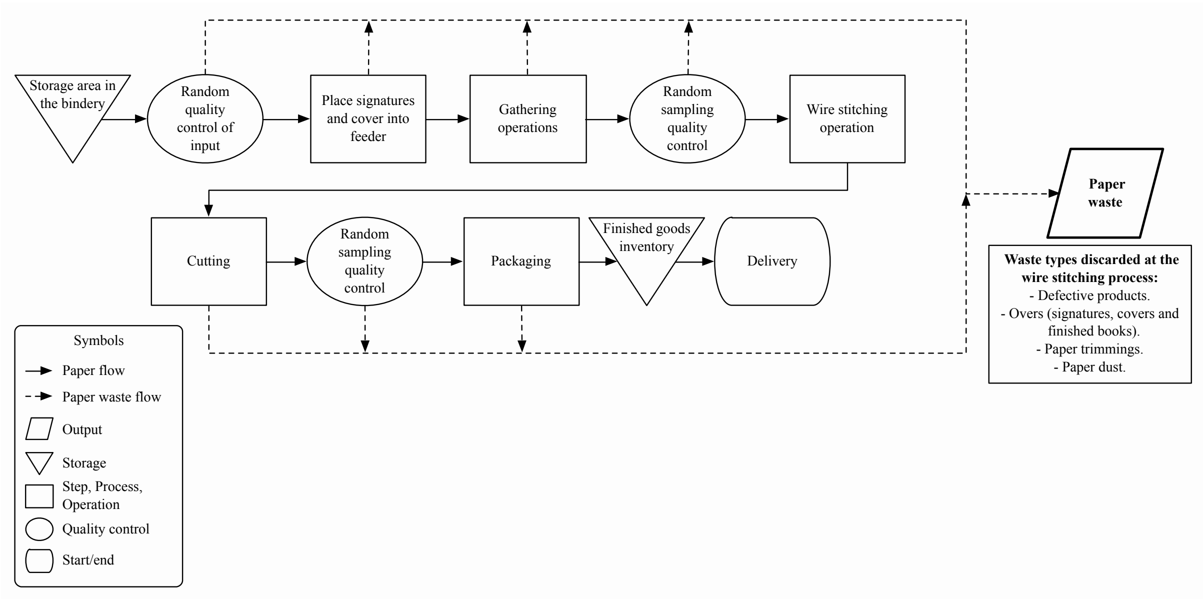

Figure 15. Process map for the Wire stitching department

Due to the inherent variability of the printing and binding processes, anticipating the exact quantity of paper which will be consumed by a job is difficult. Therefore, extra quantities known as overs are produced in every step of the production process to ensure that ordered quantities of the final product are met. Overs are included in the net number of sheets calculated for a job, and provide a certain leeway in production allowing for setup sheets and other types of spoilage in each production step. The calculated percentage of overs varies between jobs. However, when a job proceeds better than planned and fewer sheets are spoilt during the production process than anticipated, overs can result in more finished products than ordered by the customer. At other times, the situation is the opposite, and the overs are not enough to cover the spoilage, resulting in fewer finished products than ordered. Therefore, it is industry standard for printing companies to be able to, within a predefined range, deliver either additional or fewer products than ordered to customers. The standard makes it more desirable to overdeliver than to underdeliver quantities as excess products can be billed. At the company some customers accept this standard while others require the exact ordered quantity to be delivered.

To avoid the large costs associated with reprinting products, some overproduction is seen as a necessary and integral part of production, and is considered to be the best way to handle the variability of the production process today. This way of working and the difficulty of anticipating how many overs are needed for a job has implications on paper waste in the binding operations. How many overs a job requires is known first after the printed product has gone through all necessary production steps. For an edition consisting of many signatures, the underproduction of one signature becomes the limiting factor of how many finished products can be made. Sometimes this entails that many already printed signatures become excessive and are therefore discarded. Therefore the largest source of paper waste generated in both the adhesive binding and wire stitching station is unneeded overs in the form of finished products or signatures. However, although buffers exists and generate large amounts of waste, approximately 6,7 percent out of orders printed during the measurement period delivered fewer products than ordered to customers. The total amount of orders that delivered under the ordered customer quantity may however be even higher, as information regarding delivery amounts was not always available in the ERP-system.

4.4 Identified problems with manual reporting

Throughout the production process, operating time, material usage and output quantity among other things are manually reported into the ERP system. Manual reporting provides the basis for cost accounting in each step of production and gives input on material consumption to the purchasing function. Although reporting is supposed to be done continuously and consistently within each function, the quality of reporting varies. Below identified deficiencies of current reporting practices are presented.

4.4.1 Paper consumption

To keep track of how much paper has been used for a job operators at the different printing presses report the paper consumption of each job manually into the ERP system. Reporting should be done in the same way by all operators but since it is done manually, what gets reported and how, differs between operators and presses. During the measurement period the reporting of paper consumption varied among the different presses as can be seen in figure 16. For a large majority of the jobs printed in the 708 and 705 presses, paper consumption was reported for all printing operations. For the jobs printed in the 704 printing press paper consumption was not reported at all in more than a third of the cases, and only partially reported for over a quarter of the cases. Thus, for the jobs printed in the 704 press during the measurement period, paper consumption reporting was imperfect in one way or the other in 65 percent of the cases. The lack of accurate paper consumption data affects the operational buyer’s ability to adequately supply production with paper since the inventory stock levels are based on the reported consumption.

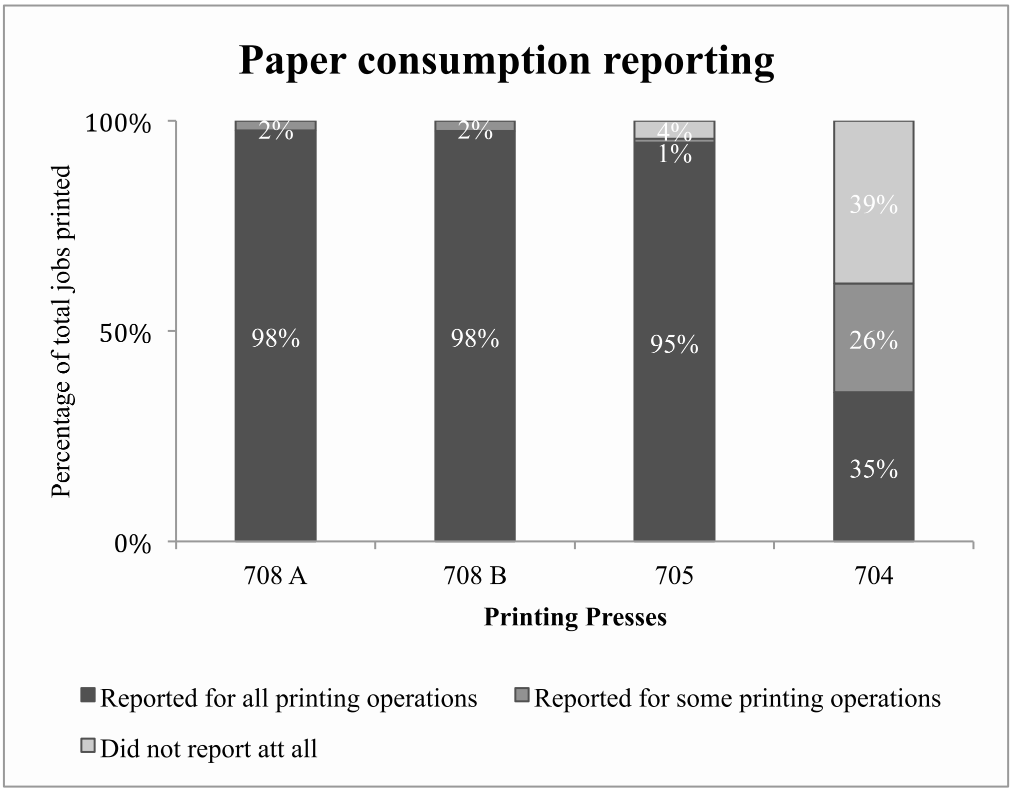

Figure 16. Paper consumption reporting.

4.4.2 Imprints

Imprints are also reported manually by the press operators, and comprise all imprints made in the press including those for make-ready sheets and actual production. In figure 17 a comparison is made between reported paper consumption and reported imprints for jobs, where reporting was done for all printing operations in the 708 A, 708 B and 704 presses (in the 705 press some jobs require sheets to go through the press twice which makes imprint and paper consumption figures incomparable). The figure shows that in a large majority of the cases the reported paper consumption was the same or below the reported imprints for the job. This implies that potential paper discarded in offset production before and/or after printing in form of e.g. packaging material and surplus paper, is often not included in the reporting of paper consumption. Therefore even for the jobs where paper consumption has been reported for all printing operations, it can be questioned if the figures reflect the actual paper consumption in the offset production.

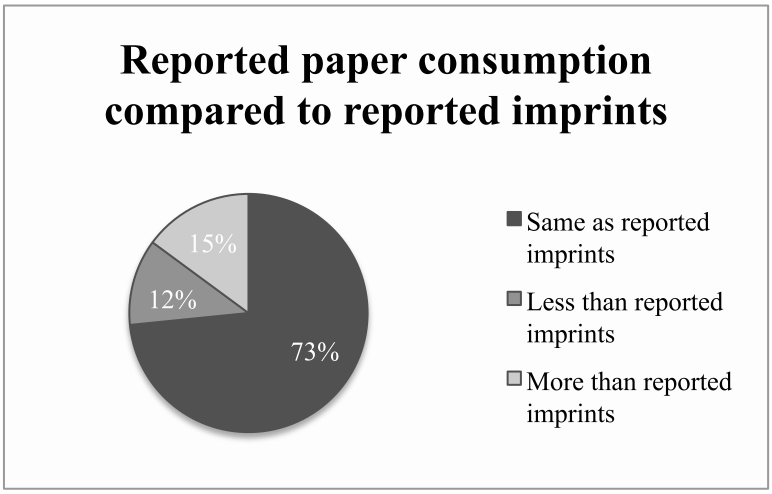

Figure 17. Reported paper consumption compared to reported imprints.

Manually reported imprints are used as basis for job costing and are therefore required for every order. Imprints are however also recorded automatically through built in counting mechanisms in the printing presses. Since the figures from the presses are automatically registered they are assumed to be more accurate and reliable than the manually reported figures. As can be seen in figure 18, weekly figures from the individual printing presses do not always match the manually reported numbers and can differ significantly for the same week and press. For some weeks and presses more imprints have been reported than registered in the presses, which is indicated by a negative value in figure 18, and for other weeks the situation is the opposite. The observed differences indicate that manually reported figures do not always accurately portray the true activities of the printing presses and may hinder assessing the presses actual performance. Reported figures and press figures will never match completely as reported numbers are approximates, but large discrepancies are reason for concern as they affect cost accounting, and may affect inventory figures as it is common that reported imprints also are reported as consumed paper as described above. Moreover, as the automatic reporting is deemed to be more reliable than manual reporting it can be questioned whether or not manual figures for imprints need to be reported at all.

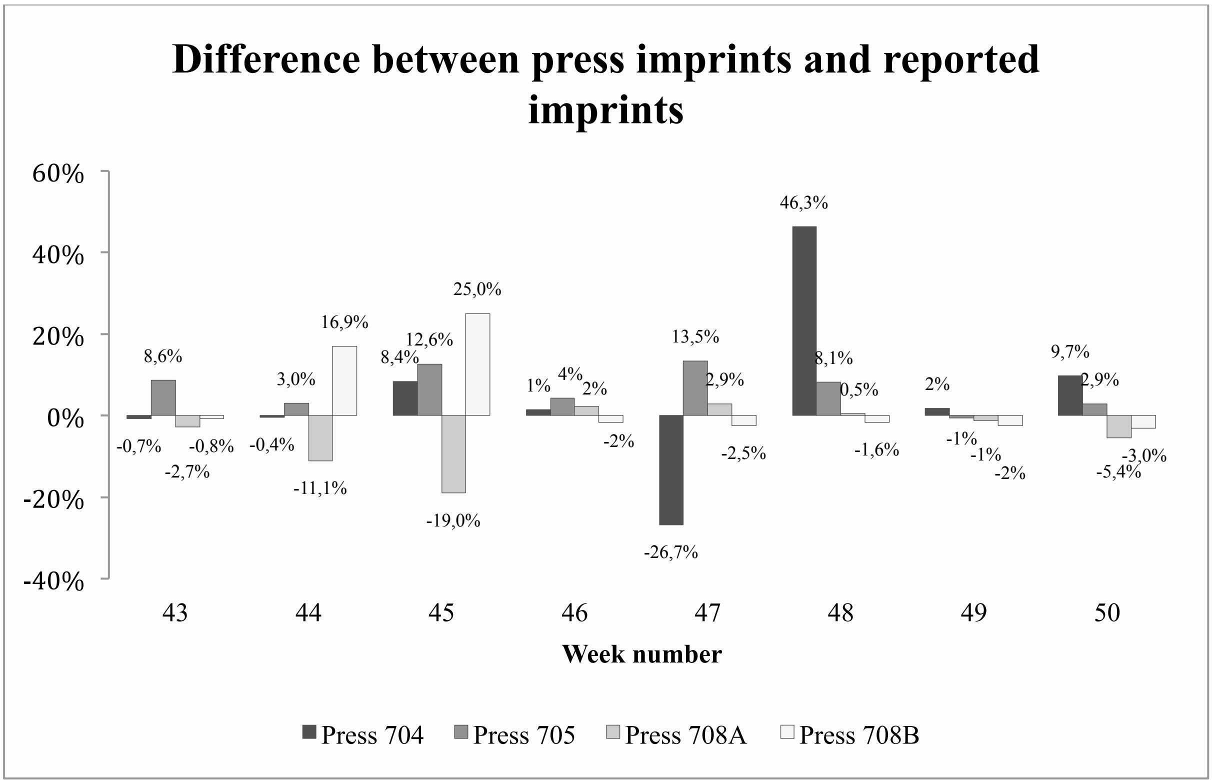

Figure 18. Difference between press imprints and manually reported figures

4.4.3 Bindery

In the bindery manual reporting is also done. However, just as in offset production the quality of the reported data is questionable. For some orders information such as e.g. setup sheets used in the folding department and the quantity of finished product delivered to the customer has not been reported at all into the ERP-system. During the measurement period 27% of the completed orders were lacking figures on how many products had been delivered to the customer, and paper quantities for setup sheets in the folding function had not been reported at all for any order.

4.4.4 Procurement

Moreover, as a result of inadequate documentation, delivery-specific information is currently lacking in the ERP-system. A barcode scanner is supposed to be used to register incoming paper, but in actuality deliveries are manually registered. The scanner system was abandoned fairly quickly after its implementation, as it was deemed too time consuming due to malfunctions and incorrect updates in the inventory system, and thereby required manual adjustments. This has affected access to delivery information since manual changes of inventory levels are not traceable, and therefore not visible in the ERP-system. That the scanner system had been dismissed by the logistics department was however unknown to other departments. The reasons for implementing the system had not been clearly communicated, so to reject the system and register incoming material in another way was never considered to affect other parts of the organization.

Inadequate manual reporting decreases the reliability of the production data and undermines the ability to monitor and control the production process. In the case of paper, insufficient reporting impedes the ability to determine how much has been consumed for a job or over a specified period of time, how much has been transformed into waste, and where in production paper waste arises. Moreover, it distorts inventory figures and makes accurate job costing difficult.

4.5 Quantification of paper waste

To determine where in the production process paper waste is generated and how much each process step contributes to the paper waste stream, an attempt was made to quantify paper waste streams in all steps of production during a two-week period. The quantification entailed weighing all paper waste containers in production, collecting detailed information from the ERP-system on all orders going through production, and collecting information on purchased, stored and returned paper. Specific order details included information such as the theoretical amount of cutting waste, paper used, and the number of delivered copies per order. This information was gathered in order to quantify input and outputs. First the choice of measurement period will be discussed, followed by input and output quantifications. Lastly the findings and results of the quantifications are discussed.

4.5.1 Choice of measurement period

The collection of data was carried out during a two week period between the 16th and 30th of November 2015. The period was chosen based on discussions with a production planner and the head of production regarding the representability of the two weeks. The intention was to measure over a period of time that reflected normal operating conditions and included the natural variation of the process. Factors that were used to determine the representability included planned number of jobs, order sizes, capacity utilization, planned maintenance and customer presence. An attempt to identify representative weeks based on the analysis of historical production data was also made. However, the historical data was considered to be inaccurate, and therefore the attempt was discontinued after a short while. Moreover, it was known that the measuring would interfere somewhat with the daily work of the logistics personnel, and therefore the head of logistics was consulted to determine how long such interferences could be accepted. Two consecutive weeks was determined to be an acceptable timespan.

4.5.2 Quantifying input material

To determine the amount of paper supplied to the production process during the measurement period, purchasing records, stock balances and returns were examined. Initially it was believed that detailed purchasing information could be extracted from the inventory database, but due to poor documentation routines for incoming material it was concluded that the available information in the database would be of little help.

To obtain incoming paper quantities, all delivery notes during the measurement period were therefore collected and registered manually into a spreadsheet by the authors. To complement the purchasing information, inventory logs for all available paper qualities were extracted from the inventory database before and after the measurement period. This in an attempt to deduce how much had been taken out of stock and used in offset production for the period. Moreover, the quantities of paper sent back to vendors during the measurement period were registered in a check sheet by the operational buyer and made readily available to the authors.

However, when inventory logs were compared to delivery notes, produced orders and paper returns, it became clear that the inventory figures were inaccurate, and that they could not be used to determine how much paper had been used from stock during the period. The amount of paper that went into offset production during the measurement period could thus not be accurately determined and not used as basis for waste percentage calculations as initially thought. Instead the collective weight of the gross number of sheets calculated for each printed order has been used as denominator in waste percentage calculations for the measurement period. The gross number of sheets was considered to be the second best option as it reflects the amount of paper 'needed' in production for each order.

4.5.3 Quantifying paper waste in production

Since the quantification of paper waste required a lot of cooperation and help from the logistics and production personnel, information regarding the measurement period was conveyed to all relevant departments at department meetings. The purpose and approach of the investigation was clearly explained prior to the measurement period and employees were given several opportunities to ask questions to the authors regarding the project. During the two-week period paper waste was quantified through the weighing of full paper waste containers in production. The weighings were performed by the logistics personnel in conjunction with their daily emptying routines, and done using the built in scale in one of the forklifts. The weights of the full containers were registered in a data collection form along with information regarding size of bin, location in production and date. See appendix I for the complete data collection form. Surplus paper from production, which is to be discarded, is not always thrown into the waste containers but sometimes placed on pallets as it simplifies handling for the logistics personnel. This type of surplus paper was also weighed by the logistics personnel during the two-week period and registered in a separate form, which can be seen in appendix II. A number of empty containers and pallets from each container and pallet category were then randomly selected and weighed, and their weights used to arrive at averages. The average weights were then subtracted from the weights of the full containers and pallets to obtain the weight of the paper waste.

To ensure that the data collection forms were filled out, reminders were placed in all forklifts so that no paper would be thrown away without being weighed first. Furthermore, the researchers made several visits to production during the measurement period, approximately four per day, to check that waste containers had not been mixed and that measurements were taken. Moreover, several conversations with production personnel, logistics personnel and the operational buyer were conducted during the measurement period in order to obtain complementary qualitative data during the same period.

After the measurement period it was discovered that the scale, which was used to weigh paper waste containers, was not precise meaning that multiple measurements of the same object resulted in different weights. Since the weighings could not be repeated an attempt to assess the reliability of the weights was made. It was assumed that the impreciseness of the measurements were caused by random error generated by the same phenomenon for all weighings. Therefore it was assumed that the random error could be estimated by approximating a mean coefficient of variation for two additional sets of data obtained with the imprecise measurement system. The assessment entailed weighing the two types of empty waste bins 16 and 12 times respectively in a randomized order with the same scale as used during the measurement period. The means and standard deviations of the two data sets were then calculated and used to compute the coefficient of variation (CV) for the two sets. The individual CVs were then used to calculate a mean CV. Table 5 displays the main findings from the reliability assessment. The mean CV was found to be 16,25% and is assumed to represent the dispersion around the mean for all measurements made with the scale.

Table 5. Main findings from reliability assessment

	Small waste bin	Large waste bin
Sample size	12	16
Average weight (Kg)	238	292
Standard deviation (Kg)	40	46
Coefficient of variation (%)	16,7	15,8
Mean coefficient of variation (%)	16,25	

Since there is an uncertainty in the precision of the weights, the findings from the weighings were triangulated with data from the recycling partner and observations made in production in order to assess to what extent the information corresponded. The total weight of all paper waste collected by the recycling partner during the measurement period was 61 422 Kg, and the total weight of the measured and calculated paper waste in production for the same period was 64 025 Kg. The difference in percentage between the collected and measured paper waste therefore amounted to approximately 4,15 % percentages. This indicates that the results from the weighings and calculations are fairly close to what was collected and recycled during the period despite the uncertainty of the measurements. Moreover, the results from the measurement period agree with observed phenomenon in production. For instance, it was observed that paper waste is less densely packed in the folding department than in the cutting department, and also that many of the waste containers in the folding department are smaller than in the cutting department. Therefore it was assumed that an equal number of empties in the two departments would lead to higher weight in cutting and lower weight in folding. The actual weighings confirms the assumption (see table 6): 31 empties in the folding department generated 10 percentages of the total measured weight, and 26 empties in the cutting department generated 19 percentages of the total measured weight. This reasoning applies to other weighings as well. From the daily observations in production it was qualitatively judged that the offset printing department was the single largest source of visible paper waste. This corresponds with the numbers from the weighings, which indicate that approximately 42 percentages of the weighed paper waste came from offset.

As the weighings correspond with other sources of data, they are believed to indicate the main problem areas within the production in regards to paper waste. However, the waste amounts from the weighings should not be seen as true, but instead as rough estimates of waste quantities during the measurement period. By itself the measurement data should be used with great care, but in combination with other results it helps describe the current state.

As previously mentioned not all paper waste is discarded into the waste containers. A portion of the paper trimmings is instead sucked into the central waste extraction system and transported directly to the compressor. The results from the weighings therefore do not represent the total amount of waste generated in production and need to be complemented with an estimate of the trimmings that went into the extraction system for an accurate picture of paper waste to emerge. Therefore the total quantity of paper waste that was cut and trimmed away during the measurement period was calculated using the paper utilization rates and the net number of sheets needed for each individual order. Adding the calculated quantity to the weighed generates a more comprehensive portrayal of the paper waste but it also introduces more uncertainty to the numbers. As the cutting and trimming waste which is thrown into the containers unavoidably become included in both the calculated figures and in the figures from the weighings. To best display how the calculated numbers affect the results, only the results from the weighings are presented in table 6, while both the results from the weighings and the calculated cutting and trimming numbers are presented in figure 19.

4.5.4 Results

The results from the conducted weighings during the measurement period are shown in table 6. The table is categorized into eight groups based on where in production the waste is discarded. Six of the categories represent where the waste containers are located in production, the logistics category represents surplus paper on pallets and the category labeled ‘other’ includes waste quantities produced in departments outside of the scope of the study. The results from the weighings are presented as percentages of the total amount weighed so that how much each category contributes to the waste stream can be easily assessed. Also included in the table are the number of empties made and the main composition of the waste in each category. The assessment of waste compositions is based on information from daily observations in production during the period. In table 6 the number of empties is not applicable for the logistics category since surplus paper on pallets is not emptied in the same way as waste in containers.

Table 6. Results from the measurement period excluding calculated cutting waste

Area of disposal	Percentage of total weighed paper waste	Nr. of empties during the period	Most common composition of paper waste in waste containers
Offset -delivery unit	31%	39	• Make-ready sheets from offset
Cutting	19%	26	• Make-ready sheets from offset • Large trimmings
Logistics	12%	Not applicable	• Surplus paper returned to the logistics department after printing
Offset -feeding unit	11%	67	• Damaged paper and packaging material • Surplus paper from production discarded by printing operators • Make-ready sheets from 705 press
Folding	10%	31	• Make-ready sheets from offset • Set-up sheets
Adhesive binding	10%	16	• Overs • Set-up copies
Wire stitching	6%	8	• Overs • Set-up copies
Other	1%	1	

Adding the calculated cutting and trimming waste to the figures from the weighings in table 6 results in figure 19. Figure 19 indicates that the amount of paper that was cut and trimmed away represents the single largest source of paper waste in production during the measurement period. This implies that overall quantities of paper waste are largely affected by the imposition of content onto the sheets and the choice of paper format.

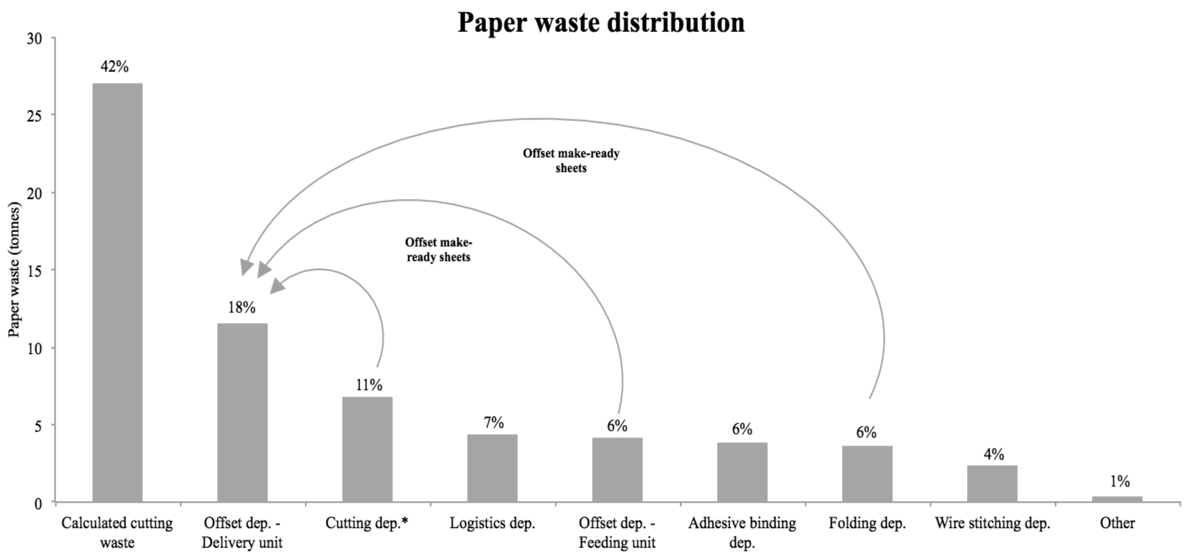

Figure 19. Paper waste quantities including calculated cutting and trimming waste

The results also indicate that the offset department is a large contributor of paper waste in production in the form of make-ready sheets, surplus paper and damaged paper. Table 6 indicates that the greater part of the waste from offset came from the delivery unit and was composed mainly of make-ready sheets, but also that surplus, damaged and packaging paper from the feeding unit made up a significant part of the waste stream. The waste composition row in table 6 and the arrows in figure 19 show that make-ready sheets from offset are commonly discarded in succeeding process steps such as cutting and folding and by the offset feeding unit, which implies that an even larger portion of the waste quantities than displayed can be attributed to the offset printing department. Consequently, the offset department accounted for at least 24% of the total generated waste during the measurement period. From table 6 it can also be seen that the number of empties in the offset department amounted to over 50% of the total empties made, which indicates that a majority of paper waste handling in production was connected to the offset department during the period.

Moreover the results indicate that waste in the form of surplus paper from the logistics department contributed significantly to the paper waste stream. This highlights the previously discussed problem of not being able to take care of or store leftover paper from production and that considerable quantities of unused paper are currently being discarded.

As can be seen in table 6, waste from the binding operations is generated largely in the form of discarded overs, which emphasizes the difficulty currently faced by the company of matching estimated quantities with actual quantities needed to finish a job. Overs are also discarded after folding operations, but the contribution to waste in the form of overs is less from the folding department as the bulk of the paper waste there was observed to be offset make-ready and folding setup sheets.

The total percentage of waste generated during the measurement period amounted to approximately 34-38 % of the total quantity of gross sheets calculated for all printed orders. The figure equals 38 % if the unknown quantity discarded into waste bins from the cutting and trimming department is accounted for twice. However, if the total quantity of waste weighed form the cutting department is excluded the figure amounts to 34 %. Consequently, the total percentage of paper waste generated during the period lies somewhere between 34-38 %. Based on the calculations for paper waste performance indicator in table 4 in section 4.2, it can be concluded that the paper waste percentage for the measurement period is close to the displayed average.

In summary it can be concluded that a majority of the paper waste stemmed from the cutting and offset printing departments but that the potential to minimize paper waste was identified in all studied parts of production during the measurement period. Individual waste compositions are currently difficult to rank since waste can travel through the process and because waste from the same category can arise at several steps within the process. As previously stated offset make-ready sheets can be discarded at the offset delivery unit, the cutting department, the folding stations, and by the offset feeding unit. Moreover, both offset printing operators and logistics personnel discard surplus paper, and overs are commonly discarded after both folding and binding operations. Therefore, it is difficult to assess how much for example overs and surplus paper contribute to the paper waste stream respectively. However, although exact figures stating how much each paper waste type contributes are difficult to extract from the measurements, the largest contributors have been identified, and it can be concluded that potential for improvements exist. The main result from the measurement period is the identification of areas that could be of interest to further investigate and where large improvement potentials exist.

5. Discussion

In this chapter the developed theoretical framework and empirical findings will be discussed simultaneously. The aim of the chapter is to generate different paper waste reduction alternatives and evaluate the company's waste management efforts according to literature.

5.1 Current waste management focus

The company's waste management practices are currently focused on recycling and recovery, two intermediate steps of the waste management hierarchy presented in figure 1. The close relationship with the recycling partner has resulted in all paper waste being off-site recycled whenever possible or otherwise incinerated with energy recovery; nothing goes to landfill. The recyclability of waste in an organization is heavily influenced by waste collection and segregation practices (Cheremisinoff and Ferrante, 2013), and can have a significant impact on the economic and environmental performance of the entire waste management system (Davidson, 2013). At present, good recycling practices including sorting and segregation of waste streams have been put in place, and investments in machinery to reduce the volume and handling of the generated waste have been made. The company's waste management practices have thereby been directed towards making sure that generated waste is handled efficiently, that waste is recycled and that recycling revenues are earned. Consequently the company is good at taking care of paper waste, but little attention and effort is being directed towards the two more preferred levels: prevention and preparing for re-use. As recommended by for example Davidson (2013), EU (2012) and UNEP (2013) the higher levels of the waste management hierarchy should be preferred and highest prioritized, as these often entail both the largest environmental and economic benefits. Reducing paper waste quantities further in production will require reaching the higher levels of the waste hierarchy, as current waste management practices to handle generated waste are well developed. Below a discussion will be had regarding what the company can do to move up the waste hierarchy and engage in proactive waste management practices focused on prevention and reduction.

5.2 Effects of only having a high level paper waste performance indicator

Sharma (2001) argues that production changes to benefit the environment frequently get neglected as employees disconnected from the production floor set environmental programs or strategies, while production personnel mostly focus on keeping the production line up and running. At the company, paper waste is monitored with the help of a plant level performance indicator which is used by management to set overall reduction goals for the site. The paper waste performance indicator is measured monthly, but the underlying causes for the monthly figures are not investigated or analyzed. Consequently, the PI currently does little to increase the understanding of paper waste and its causes. On production level the PI targets have little effect on paper waste reduction as the production personnel mainly focuses on keeping the production up and running. This can be seen in the current view held by production personnel where paper waste is regarded as a natural part of the process. There is currently no commitment to the reduction of paper waste and it is therefore unprioritized by both operators and managers on production level. For paper waste targets to have effect, the goal of reducing paper waste therefore needs to be better rooted in production practices. A way to do this can be by increasing the commitment and awareness of environmental aspects in production by establishing accountability for waste generation (Franchetti, 2009; WMRC, 1997).

5.3 Establishing accountability through performance indicators

Today there is little accountability for paper waste as its generation is poorly documented and existing figures are not followed up. Cheremisinoff and Ferrante (2013) suggest that accountability can be established by implementing reduction programs aimed at holding managers responsible for reporting on waste quantities from their respective departments. At the company this could encompass introducing department specific paper waste goals and performance indicators. To ensure that accountability is established on shop-floor level, and to drive change at lower levels of the organizational hierarchy, indicators should be implemented on source or machine level (WMRC, 1997). For offset production this could entail establishing a performance indicator for make-ready percentages based on the automatically reported figures from each printing press. The performance indicator would not capture all paper waste generated at the printing presses, but it would nonetheless display the department's largest source of paper waste. The indicator could then be used to monitor make-ready levels and establish baseline data to build an understanding for the normal variation and performance of the process. Ultimately the generated baseline data could be used to improve make-ready calculations and set realistic make-ready reduction targets. Furthermore, since the manually reported amount of imprints often differ from the ones automatically reported by the presses (which can be seen in figure 18), the printing operators might not even be aware of the quantity of waste they actually generate. A make-ready performance indicator could therefore be used as a communication tool to create a sense of accountability and awareness in regards to current paper waste quantities within the offset printing production. In all other parts of production indicators for the largest sources of paper waste should also be introduced. In the bindery this could mean introducing a metric for discarded overs, in the folding department it could entail establishing an indicator for required setup sheets, and in the logistics department the quantities of discarded surplus paper could be monitored.

Managerial source reduction practices such as creating awareness and accountability by establishing environmental performance indicators requires that current reporting practices are updated and improved. In the beginning it can be difficult to obtain accurate figures, as the reporting system is mainly built on manually reported numbers. Therefore, clear instructions for reporting practices is needed to decrease the chance of obtaining misleading data, and follow ups to assess the reliability of data will also be required. Inaccurate data poses a problem if it is to be used to conduct deeper analyses to increase process knowledge and find new improvements. However, a first step should be to create awareness and gain commitment within the organization, and even if data accuracy can be questioned, established measures can still create a common goal to work towards in initial stages, which in itself can be very beneficial. The benefits of establishing indicators in terms of increased process knowledge must be set in relation to the time it takes to gather metric data and prepare reports, but it should be stressed that having accurate and available production data is a prerequisite to obtaining a real understanding of the paper waste situation and to be able to effectively reduce waste. Furthermore, which indicators are to be introduced needs to be further discussed, for example if make-ready sheets are to be used instead of sheets of sufficient quality during folding setup (see chapter 5.7), a performance indicator related to the number of setup sheets used in folding might not be a good indicator. Folding operators might feel unmotivated to decrease a waste that would occur anyway, it might therefore be beneficial to create a measure which displays increased output instead.

5.4 Effects of reporting practices and the importance of reliable data

The audit frameworks presented in chapter 2.2 emphasize the importance of having accurate data and a comprehensive understanding of the material flows to be able to find root causes for waste generation, and for identifying waste reduction opportunities in production (UNEP, 1991). The current lack of reliable reporting, discussed in chapter 4.4, which has resulted in inaccurate and in some cases even missing information therefore poses a challenge for efficiently working with waste reduction at the company.

Inadequate manual reporting has decreased the reliability of the production data and has undermined the ability to monitor and control the production process. In the case of paper, inaccurate data has impeded the ability to determine how much has been consumed for a job or over a specified period of time, how much has been transformed into waste, and where in production paper waste arises. For the company to be able to identify and eliminate causes of paper waste, reporting structures and routines therefore need to be looked over and the quality of the reported data improved. Having a high quality of data is also a prerequisite if performance indicators are to be introduced and accountability for paper waste is to be established. Inaccurate data affects the ability to monitoring and follow up production performance, which is critical in determining whether set targets are met and whether improvement efforts have had intended effect (UNEP/DEPA, 2000). Moreover, inaccurate and missing paper consumption data currently distorts inventory figures which obstructs the ability to control inventory levels, and has resulted in the need to manually adjust inventory levels regularly. Improved reporting practices is therefore also a first step in obtaining accurate and reliable inventory information.

The lack of available production data also hinders the ability to more accurately assess how much paper is needed to accommodate faults, inaccuracies and make-ready sheets in production, something which is currently difficult and leads to waste in the form of overs and surplus paper. Unless the quantities being consumed and the requirements in terms of overs for each job are known, gross sheet estimates will be difficult to improve. Thus, a first step towards better estimates is obtaining accurate information on paper consumption and waste generation throughout production. Another step towards reducing excess quantities printed to accommodate inaccuracies is to improve the accuracy of counting methods in production (WMRC, 1997).

5.5 Identified housekeeping improvements

The most common techniques used to reduce waste within the printing industry are either good housekeeping practices or material substitution efforts (WMRC, 1997). Moreover, as efforts classified as improved operating practices often can be implemented at a lower cost and quicker than other source reduction methods (EPA, 1992), it can be beneficial to explore these initially. Improved operating practices are common ways to reduce waste at the source through for example improvements in material handling, production scheduling and inventory control practices (EPA, 1992).

The reasons for large amounts of unused paper being discarded at the company are many and stem form a combination of factors. The large variety of paper qualities used, gross sheet calculations, inaccurate inventory figures, deficient paper handling practices, and last-minute changes in production scheduling combined with the current VMI-system and manual ordering procedures, all affect the generated quantities of surplus paper waste.

The amount of incoming material, and thereby hopefully the generation of waste, can be reduced by accounting for stocked quantities when ordering new material. As stated by Weinrach (2001) procurement quantities can be limited if information on stored material is known. Unreliable inventory figures currently increase the risk of making suboptimal purchasing decisions, as VMI-deliveries have to be manually canceled if paper available in stock is to be used. Reliable inventory figures can also be used to make more informed decisions in regards to paper returns and storing availability. Having high quality inventory data is therefore a prerequisite for better inventory control and can improve purchasing and paper handling practices, which in turn helps reduce the unnecessary discarding of paper. Reporting structures within the offset printing process and the logistics department therefore need to be updated, in order to increase the accuracy of inventory figures. Moreover, if surplus waste quantities are to be reduced, paper handling and management procedures within the logistics department need to be updated. Improved housekeeping procedures can be implemented relatively easy through changes in procedural instructions for storage and material handling (El-Haggar, 2007). Therefore, new standard procedures which takes available inventory figures into account when deciding if surplus paper quantities should be returned, stored or scrapped should be implemented, after the reliability of inventory figures have been improved.

Another example of good inventory control practices is the use of JIT procurement (Weinrach, 2001). The current VMI-system sets out to provide the exact amount of paper needed in production within a 12 hour period. However, last-minute changes reduces the benefits of the current setup, as these changes lead to discrepancies between needed and delivered material. Last-minute changes to production scheduling does not only lead to increased handling of paper and reduced availability of inventory capacity, it can also affect the generated amount of make-ready sheets. Efficient and effective production scheduling, such as running similar jobs after each other, reduces make-ready and changeover spills (WMRC, 1997). Scheduling production to decrease waste generation becomes difficult as changes are common and arises on short notice. Why last-minute changes in production occurs and how these can be reduced should therefore be investigated, to increase the benefits of the current VMI-system and to increase the ability to schedule similar jobs after each other and thereby reduce waste quantities.

5.6 Possible input material changes

Input material changes avoids the generation of waste within the production process or reduces the quantity of waste entering the production process (Smith, 2004). Within the printing industry this may include designing layouts to fit sheet sizes, as it reduces the quantity of waste generated within cutting and binding operations (WMRC, 1997). Thereby, the company can either increase the number of sheet sizes used or improve current imposition practices. Increasing the number of paper qualities used would however largely affect the complexity of purchasing and paper handling practices, and possibly lead to an increase in waste quantities from these departments. It might therefore be beneficial to improve current paper management practices prior to changes such as this, if both are to be implemented. If the complexity of paper handling operations are increased when actions to improve the efficiency are made, resistance to change can arise and inhibit improvements. Thereby the benefits of introducing more qualities can be lost as waste and handling costs could increase within the logistics department. Furthermore, there is a possibility that introducing more sheet sizes can affect the ability to supply production with materials negatively with the current setup. Increasing the number of varieties reduces the ability to “borrow” paper between orders, which is a common, although undesired practice today.

Improving imposition practices, such as fitting two jobs on a sheet or decreasing bindery trim size, would also increase sheet utilization rates. This improvement alternative would however increase the complexity of the production process and the risk of faults and defects. Furthermore, it would probably involve investments in new software or employee training programs due to the complexity and risk involved in such a change. If this option is viable or not should therefore be evaluated by employees with sufficient and deep process knowledge. However, as the single largest paper waste contributor is cuttings and trimmings, changes aiming at reducing these quantities should be considered as the gains can be substantial.

5.7 Reusing paper waste

Other source reduction techniques involve reusing waste paper, such as printing on both sides of a make-ready sheet (WMRC, 1997). Therefore reusing paper should be employed whenever feasible throughout the production process. At the company alternatives for reusing paper waste include:

- Reusing make-ready sheets in offset production for jobs that require going through the presses twice.
- Using offset make-ready sheets during folding setups instead of high quality printings.

If wasted paper is reused the overall quantity of paper waste and paper consumption can be reduced. The potential effects of using offset make-ready sheets during folding setups could also lead to more overs being sold or fewer instances of under production occurring. The output from folding operations can increase if high quality printings are not used for setup, and thereby the output from binding operations can increase as well. Furthermore, long-term potential effects could even be a decrease in the amount of net sheets required in post-press operations, as offset make-ready sheets can replace buffers included in the net amount of sheet.

Reusing waste paper in folding operations entails preparatory steps in offset printing and cutting to enable the change, which can create resistance. It therefore becomes paramount to communicate the benefits of the change, and how it affects the production in later stages of the process. Furthermore, a detailed instruction of new additional practices within the production process is needed in order to assure that make-ready sheets are not mistaken for sheets of high quality in subsequent process steps. Moreover, before implementing the change it can be beneficial to pilot test procedures until the most effective way has been identified, and to be able to create detailed instructions in order for misunderstandings to be limited. It might also be beneficial to discuss the change in a group setting where operators from offset, cutting and folding are present in order to create motivation and a willingness to change.

5.8 Sales and customers impact on environmental performances

As customer choices and specifications can affect the environmental performance of a printing process to a great extent, information and pricing signals should encourage decisions which reduce the environmental impact (Franchetti, 2009). The current evaluation of "in-house" paper is a step in this direction. If sales personnel starts promoting standard qualities to customers and creates awareness of the environmental impact of their choices, the number of paper qualities used can be decreased. Thereby, less surplus paper quantities could end up as waste, as fewer paper qualities would facilitate the handling of and ability to store paper.

5.9 Mindset, attitudes and change

The current mindset and attitude towards paper consumption seems to have a large effect on waste quantities. For example, in the offset printing process the gross amount of sheets calculated for an order are "supposed" to be used, and decreasing make-ready sheets or other types of paper waste may result in surplus paper which is discarded anyways due to deficient paper handling practices. Therefore little incentive to reduce paper consumption currently exists. Furthermore, since current paper handling and inventory control practices are deficient, discarding surplus paper is deemed necessary due to the large number of paper quantities and low inventory capacity. Moreover, because of the variability of the production process overproduction is needed and safety buffers are therefore viewed as reasonable. Consequently, employees see paper waste as an expected effect of the current system, and therefore do little to influence the output. Thus there is a need at the company to create incentives and motivation for waste reduction, which can be done by introducing training programs and reward systems (UNEP, 1991), as well as through clearly communicating underlying reasons and necessary changes needed for reducing waste (Franchetti, 2007). Moreover, Sharma (2001) recommends that incorporating and clearly defining environmental responsibilities into job descriptions are crucial if environmental efforts are to be realized and for waste management programs to reach full potential. Consequently, current operating practices need to be updated to include activities which can lead to reduced waste. For example, in order to enable the re-use of offset make-ready sheets during folding setup, procedural changes in offset, cutting and folding are required if the change is to be institutionalized. If changes are to be sustained and institutionalized, as stated by Bergman and Klefsjö (2010), improvements need to be consolidated through for example standardization such as introducing new standard procedures.

A common source of workforce resistance to change is a lack of awareness of corporate goals and objectives (Crittenden and Kolaczkowski, 1995). To bring about change it is therefore important that information about upcoming improvements and their underlying reasons are properly communicated (Franchetti, 2007). To create employee buy-in for efforts aimed at reducing paper waste at the company, the results from this study could for example be used to establish awareness of the current paper waste situation in production and help drive change through the knowledge on large paper waste contributors which has been established. The results can also be used to focus efforts and build business cases within the company in order to gain commitment from different stakeholders. Furthermore, as emphasized by UNEP (1997) providing feedback on waste reduction performances to employees are important in order to reduce waste in the long-term. Communication before, during and after changes are thereby key in order to drive change. If performance indicators or measures are implemented on lower levels, these can be used as communications tools during all stages. Moreover, if changes are to be made the expected benefits need to be clearly communicated and obtained benefits displayed after implementations. Feedback is very important in this case as changes in one step of the process can reduce waste in subsequent steps, benefits therefore need to be made visible to the ones evoking them in order for changes to persist.

5.10 Other reduction alternatives

In order to find and generate more waste minimization alternatives connected to different waste streams, the company could also as recommended by EPA (1988) use brainstorming sessions or other groups decision techniques to generate more options. Furthermore, as paper waste is a cross-functional problem and changes in one part can affect others, waste minimization options should not only be discussed within single departments. Moreover, as employees with process knowledge often generate the best ideas (Weinrach, 2001), it can be beneficial to consult operators for improvement suggestions. Furthermore, as suggested by Franchetti (2009) discussions with plant engineers, equipment manufacturers, trade associations, and environmental consultants, as well as benchmarking and using literature can all provide the team with valuable input for creating alternatives. Initial brainstorming session, with the goal of generating more alternatives, should however be based on findings from this report.

Several other source reduction options which can be utilized, such as improving maintenance procedures (Hunt, 1991; Khor et al., 2007), properly conditioning paper sheets to pressroom temperature and humidity before printing, and training employees to use equipment properly (Cheremisinoff and Ferrante, 2013). However, these areas were not identified to be among the largest causes to paper waste at present, and therefore not investigated in detail. Nonetheless these options should be further evaluated in the future as improvements can be present.

5.11 Continuous improvements

Reducing paper waste is a complex problem to which there is no single and easy quick-fix solution. To approach sustainability and reduce paper waste a systematic and continuous application of waste reduction methods is required. Waste audit frameworks, if continuously applied, provide a solid foundation and structure for reducing wastes (Khor et al., 2007). The continuous applications of environmental strategies is crucial for approaching sustainability and reducing waste (de Ron, 1998). A formal environmental management system provides a decision-making structure and action plan to support continuous improvements, thereby enabling changes to be sustained and waste to be reduced (UNEP/DEPA, 2000). It could therefore be beneficial for the company to integrate future waste reduction efforts into their current environmental system ISO 14001, in order to organize and structure reduction efforts. Furthermore, prerequisites for successful waste audits, and thereby reduction efforts, are forming a team responsible for the work and process (Visvanathan, 2007). At the company it is therefore important to establish a team, in order for reduction activities to not become one-time efforts, as they have previously been, see chapter 4.2. If a team responsible for waste minimization is assembled, it should consists of employees from different departments within the organization, as paper waste is a cross-functional issue, this to reduce risks of suboptimal changes. Furthermore, as recommended by Franchetti (2009) the team leader should be in a managing position in order to obtain a high degree of authority within the organization and swifter communication with management.

6. Recommendations

In this chapter the recommendations to the company are presented.

Reducing paper waste is not a one-time effort, but a continuous endeavor which requires a thorough understanding of processes and material flows. The results from this study should be seen as initial input for generating such an understanding, but it must be emphasized that continuously measuring, monitoring and analyzing production data will be necessary for a genuine process understanding to emerge at the company, and a prerequisite for substantial paper waste reductions. Below the main recommendations to the company are given and their major impacts described.

Organize waste reduction efforts and make the organization susceptible to change
Impact: Ensures that reducing paper waste is prioritized in the organization and that waste reduction efforts are coordinated and considered continuously.

- Create a cross-functional team responsible for maintaining waste reduction efforts, with a team leader in a management position in order ensure top management commitment. The team should be responsible for maintaining waste reduction and management participations, such as planning, designing, implementing and monitoring reduction activities.
- Establish overall paper waste goals and communicate these to the whole organization in order to create awareness and support for the change.
- Integrate waste reduction efforts into current ISO 14 001 structures. Make waste management and reductions an integral part of the EMS-system, in order to gain benefits from current organizational management structures.

Establish paper waste performance indicators in production
Impact: Establishes accountability for paper waste in production. Anchors environmental strategy and paper waste performance indicator in production, creates awareness of issue and sense of ownership at point of waste generation. Forces paper waste to be considered and prioritized throughout organization.

- Introduce shop-floor performance indicators that measure the largest sources of waste throughout production. Examples of suitable indicators are:
    - Offset: Make-ready percentages from automatically reported numbers in press
    - Logistics: Scrap reports for surplus paper
    - Folding: Set-up sheets and overs
    - Bindery: Overs
- Set goals and targets for the performance indicators and hold department managers responsible for reporting on the waste quantities on monthly basis.
- Display and communicate the waste figures in waste reduction team and department meetings, and analyze causes in order to identify potential improvement alternatives.

Change mindsets and create commitment
Impact: Increases motivation to reduce waste. Changes view of paper waste as necessary and minimizes resistance towards waste reduction efforts.

- Clearly communicate rationale of reducing paper by displaying current costs of paper waste to production personnel, and reduction targets and objectives of the environmental strategy to production personnel.
- Incorporate actions to reduce paper waste into job descriptions.
- Incentivize paper waste reduction in production through reward systems to create awareness and motivation. (Monetary rewards or symbolic rewards can be given to those who come up with ideas to reduce waste. Reaching departmental reduction targets should be awarded and celebrated).
- Create conditions for effective waste reduction through proper training. If procedures are to be changed, clearly communicate the reasons for the change and train employees in the new procedures.
- Continue to feedback waste performance information and hold meetings to assure commitment and to enable continuous reduction of paper waste. Remember that people with process knowledge often generate the best ideas

Improve inventory control and paper handling practices
Impact: Enables working more strategically with inventory.

- Look over procedures for handling surplus paper in offset and the logistics department and ensure that surplus paper which can be stored or otherwise used, is not discarded.
- Make decision criteria and practices for stocking surplus paper clearer and easier.
- Ensure that stock levels are taken into account when decisions regarding whether to scrap or store are made, and when purchasing decisions are made.

Reuse paper waste
Impact: Increased output from folding and binding, and decreased paper consumption in offset.

- Reuse paper waste where possible, such as make-ready sheets from offset for folding set-up.

Improve quality of reporting
Impact: Increases the quality of data. Enables understanding and evaluation of process performance so that improvement decision can be based on facts. Accurate data is a prerequisite to understand processes and to identify root causes of waste. Improves accuracy of inventory numbers and reduces suboptimal purchasing decisions.

- Offset: Improve reporting procedures and routines for paper consumption and imprints.

- Purchasing: Improve procedures for registering incoming material so that inventory changes can be traced.
- Folding: Improve reporting for set-up sheets.

Improve production scheduling
Impact: Avoiding the need to override the current VMI-system, and creates possibilities to improve production scheduling to lower make-ready usage and changeover spills.

- Find ways to lock production schedule earlier, by systematically investigating the causes for last-minute changes and thereby finding improvement alternatives.

7. Discussion of quality of research, results and future suggestions

In this chapter the quality and results of the conducted research will be discussed, and areas that may be beneficial for the company to explore in the future are also presented.

There are a couple of limitations to the study that may have affected the resolution of the findings. Firstly time and resource constraints may have affected the outcome. A longer investigation may have enabled additional waste minimization opportunities to be identified on a more detailed level in production, and enabled a deeper analysis of the production processes. Moreover, having a longer measurement period than two weeks could have captured the variation of the production process in a more comprehensive way and increased the representability of the obtained measurements. Some aspects of the collection and synthesis of empirical data may also have affected the quality of the data, such as the impreciseness of the scale used during the measurement period. However, by the means of triangulation the quality of data has been assessed and ensured to the best of the authors' abilities. Moreover, due to identified inaccuracies and reporting issues, the used secondary data has been evaluated and selected carefully throughout the study. Another constraint of the study is that all source reduction techniques have not been investigated, such as product and technology changes. The thesis therefore does not explore all possibilities to reduce paper waste.

The aim of this thesis has been to give a detailed view over the case company's paper waste situation, identify its causes and to propose future efforts to reduce the paper waste. Therefore the results of the study are specifically tailored to the case company and the industry of which it operates in. The generalizability of the case study can therefore be questioned. However, by providing comprehensive and detailed descriptions of the company's paper waste situation and the research process, the goal has been to facilitate judgment of transferability to others. The results of the study display expected causes of waste at the company compared to previous findings and suggestions in literature. The case company does for example not employ several of the basic techniques that are highlighted in literature to reduce waste, such as to explore the higher levels of the waste management hierarchy through the use of source reduction methods. The case therefore displays the results of such actions, and thereby agrees with findings from studied literature. For the company, the aim is that the results from this study will generate a foundation for working with the reduction of paper waste, and that it will provide the company with a better understanding of current production processes, waste management practices and paper waste flows. Hopes are that the study will encourage a more structured and organized procedure of working with paper waste to emerge, and that the need of continuously working with waste reduction to reach low levels of waste is clearly understood.

Based on the findings of this study, areas of future research have been identified that could aid the company in their efforts of reducing paper waste. As previously stated, investigating causes and generating improvement ideas regarding deviations and non-conformance reports at the company were excluded from the study due to resource constraints. However, the initial assessment of deviation compilations and reports showed that the most common cause leading to defectively produced products were that operators deviated from standard operating procedures. Therefore, it could be beneficial for the company to further investigate how to get operators to follow the standard operating procedures and to look over current quality control routines and structures to be able to work more proactively with quality assurance and process control and improvements.

Furthermore, while it is recommended that manual reporting procedures be improved to increase the reliability of the collected data, the company is suggested to investigate what type of data is necessary to manually report. For example in the case of make-ready sheets and imprints from the presses, automated numbers are available, suggesting that manual reporting for these may not be necessary and thus not value adding.

Lastly, although product and technology changes as source reduction techniques have not been considered in this thesis, a future investigation of the applicability and feasibility of such techniques may be of interest to the company, as they may suggest unexplored ways to reduce paper waste.

8. Conclusions

This chapter aims at answering the formulated research questions of the study.

RQ1: Where in the production process is paper waste generated and what are the main waste types that contribute to the paper waste stream?

Based on observations and measurements it can be concluded that paper waste is generated throughout the entire production process. Due to the flow of waste between departments, the composition of different paper waste types within each department, and the lack of reliable and available data in regards to paper consumption and waste streams, determining the exact contribution from each waste type and department has not been possible. However, through the analysis of measurements and observations made in production a general picture of the largest contributing departments and waste types has been obtained. The measurements and observations indicate that cutting and trimming waste is the largest contributor, followed by waste generated in the offset department. The cutting and trimming waste accounted for approximately 42%, while waste from the offset department accounted for at least 24 % of the total generated paper waste during the measurement period. Within the offset department make-ready sheets is the most common source of waste, followed by unused discarded paper. Other main contributions to waste are overs discarded in the folding, adhesive binding and wire stitching departments, and surplus paper discarded within the offset printing process and from the logistics department.

RQ2: What are the main causes of paper waste generation at the company?

After having analyzed the current state at the company a number of causes for the generation of paper waste have been identified. First of all a lack of focus on lowering paper consumption and reducing paper waste has led to the issue being neglected, and thereby unprioritized within the organization. This has created a mindset were all paper discarding's are viewed as necessary and a natural outcome of current production conditions on a shop-floor level. Lacking inventory control and housekeeping practices has made the efficient managing of paper difficult, which also leads to waste. Inaccurate inventory figures inhibits informed purchasing decisions and thereby increases purchasing and waste quantities. The need for setting up presses and other operations also generates waste. Lacking production data connected to paper and paper waste streams leads to process capabilities and requirements not being fully understood, and has inhibited the ability to work actively with process improvements and safety margins within production. The difficulty of assessing the paper needed for each order to cope with production variations, setup and spoilage, leads to paper waste in the form of overs and surplus paper. Lastly, cutting waste is designed into the process and depends on imposition choices and the few sheet sizes available to facilitate easier handling and purchasing practices.

RQ3: What actions need to be taken by the company in order to reduce current paper waste quantities?
Reducing paper waste needs to become prioritized within the organization if real improvements are to be made, therefore a cross-functional waste reduction team should be established to drive change and communicate the economic and environmental impacts of current paper waste quantities and connected reduction goals and targets. The view of paper waste as necessary needs to be challenged and commitment towards waste reduction established throughout the organization. Ways of achieving this include clearly communicating the rationale behind reducing paper waste and the objectives of the environmental strategy to all personnel. Moreover, incentivizing waste reduction through reward systems and celebrating progress is important. Feedback needs to be given to maintain participation and motivation in connection to reduction efforts. Communication is key to create awareness and drive change, and cross-functionality reduces risk of suboptimal solutions being implemented. Furthermore, reduction activities should become an integral part of the current environmental management system, as this provides a decision-making structure, supports continuous improvements, and allocates focus to the specific environmental problem of paper waste.

Accountability for paper waste generation also needs to be established in order to drive change and reduce waste quantities. Therefore performance indicators should be implemented on production level, and department managers should be held responsible for reporting these figures to the waste reduction team, and for setting realistic goals and targets. This creates ownership and helps to change mindsets. Reduction activities also need to be incorporated into job descriptions on a shop-floor level, and operators need to be made aware of waste goals and targets. Furthermore, performance indicators should be displayed to and discussed with operators to generate improvement alternatives, since people with process knowledge often generate the best improvement ideas. Moreover, if practices are changed proper training is important, in order to assure that the reasons for changes are clear and that changes are fully understood.

Reporting structures need to be updated to allow the continuous monitoring of paper consumptions and paper waste streams in order to establish targets and implement performance indicators, and to increase process knowledge and thereby the identification of causes and generation of improvements. After changes to reporting structures have been implemented, reliable inventory figures should immediately be incorporated into current purchasing and inventory practices to reduce surplus paper waste quantities. Lastly, paper waste should be reused whenever feasible throughout the process, as this can lead to increased output from folding and binding operations and reduce waste quantities.

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Appendix I: Measurement form for paper waste

Measurement form for paper waste

Fill out the form by checking the appropriate box and enter the weight each time you retrieve and empty a paper waste bin.

Date	______________

Weight	Shift		Type of waste bin			Department								
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bindery Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐
kg	Day ☐	Night ☐	Secrecy ☐	Small ☐	Large ☐	Offset Feeding unit ☐	Delivery unit ☐	Cutting ☐	Folding ☐	Bokbinderiet Adhesive bind. ☐	Wire stitching ☐	Punching & Creasing ☐	Fulfilment ☐	Logistics ☐

Appendix II: Measurement form for surplus paper

Measurement form for surplus paper

Fill out the form by entering the weight, number of pallets and pallet type each time you retreive and discard surplus paper.

Date	___________

Total weight	Quantity and pallet type			
kg	900x640	___________pcs	1020x720	___________pcs
kg	900x640	___________pcs	1020x720	___________pcs
kg	900x640	___________pcs	1020x720	___________pcs
kg	900x640	___________pcs	1020x720	___________pcs
kg	900x640	___________pcs	1020x720	___________pcs