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Improving pricing and cost control in a packaging company

Master's Thesis

Examiners: Professor Timo Kärri
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ABSTRACT

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This study aims to create a printing cost calculation model to support pricing decision making in a large packaging company. Costing is an essential tool of strategic decision making and using timely and relevant cost information is crucial for company success. The research approach of this study is constructive and the empirical research focuses on two factories located in different countries.

The study begins with a literature review on costing and cost control, which is followed by the definition of printing cost. After understanding the components of printing cost, the new printing cost calculation model is created. The new model is developed based on an analysis of existing printing cost calculations, and interviews with the employees of the case company.

The greatest challenge in the development of the new model was that the printing cost appeared to be relatively complex to calculate, and all the users of the model do not have such a deep technical understanding of the products. Therefore, several cost estimations had to be established in order to keep the model simple to use. Comparison of the new model with the real cost calculations resulted that the costs can be calculated quite accurately using mature estimations.

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Diplomityön tavoitteena on kehittää kustannuslaskentamalli fleksopainannalle tukemaan hinnoittelupäätöksentekoa suuressa pakkausalan yrityksessä. Kustannuslaskenta on hyödyllinen työkalu strategisessa päätöksenteossa, mutta käytetyn kustannustiedon tulee olla ajankohtaista ja relevanttia käyttötarkoitukseensa. Tutkimuksen ote on konstrukttiivinen ja työssä keskitytään tarkastelemaan kahta tehdasta kahdessa eri maassa.

Tutkimuksessa tehdään aluksi kirjallisuuskatsaus kustannuslaskentaan ja kustannusseurantaan. Painamisen kustannus määritellään hyödyntäen case-yrityksestä saatua tietoa sekä teoriaa. Kun painamisen kustannukseen vaikuttavat tekijät ovat tunnistettu, työssä kehitetään uusi taulukkolaskentapohjainen kustannuslaskentamalli. Uusi malli perustuu aikaisempien laskentamallien vertailuun ja henkilökunnan haastatteluihin.

Painamisen kustannus osoittautui suhteellisen monimutkaiseksi laskea ja suurin haaste mallin rakentamisessa oli se, että kaikilla sen käyttäjillä ei välttämättä ole laajaa teknistä ymmärrystä. Tästä syystä mallista oli tehtävä niin yksinkertainen kuin mahdollista, mikä edellytti tiettyjen oletusten muodostamista. Uuden mallin vertaaminen tarkkoihin laskelmiin osoitti kuitenkin, että myös estimoimalla joitakin arvoja päästään riittävän tarkkaan tulokseen.

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ABBREVIATIONS

ABC	Activity-based costing
ABM	Activity-based management
CMYK	Color model that includes cyan, magenta, yellow, and black
GAAP	Generally Accepted Accounting Principles
IFRS	International Financial Reporting Standards
TDABC	Time-driven activity-based costing

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1 INTRODUCTION

1.1 Background

There is evidence of costing since business commenced (Buxton 1940). Cost information is essential tool for management decision making, especially in the manufacturing industry (Liebers & Kals 1997; Pehrsson et al. 2013). One decision making situation wherein cost information is widely used, is product pricing (Boyd & Cox III 2002; Cokins & Hicks 2007). Because pricing has a major impact on company profitability and revenue (Hinterhuber 2008), the utilization of accurate and relevant cost information in decision making is crucial for company success (Cokins & Hicks 2007). Misleading information can cause companies to lose money on jobs they think are profitable but are not (Wiersema 1996).

The subject of this thesis was commissioned by a large packaging company. Printing cost has a significant share of its end product's total costs but there was not a common way to calculate it at production plants within the case company. The company had standardized the calculation of other production costs a few years ago but the printing cost was still calculated separately at each factory. Among other things, growing market demand in printing sector had led to that the company wanted to standardize their printing cost calculation at a group-level in order to enhance the accuracy of pricing and forecasting.

1.2 Objectives and delimitations

The objective of this study is to develop a spreadsheet model with which the cost of printing can be calculated at all production sites regardless of the location. The new model aims to support pricing decision making and ensure that all facilities use timely data in pricing calculations. After developing the cost calculation model, this study examines what are the most critical parts of the printing cost.

The research questions are as follows:

- What is the definition of printing cost?
- How is the new printing cost calculation model structured?
- What are the most critical parts of the printing cost calculation?

This thesis focuses on defining the cost of printing, and therefore it does not discuss about other production costs further. The printing cost is examined at group-level with focus on two factories located in different countries. From a theoretical point of view, this research does not comment on pricing strategies. Instead, it studies costing and how cost information can be utilized for cost control and strategic decision making, such as pricing.

1.3 Research methods

The approach of this research is constructive and it was executed as a single case study in a large manufacturing company. The main idea of constructive research, also known as design science research, is to create a solution for relevant, theoretically warranted real-world problem that is shown to work in practice and has potential to be generally applicable (Kasanen et al. 1993). The duration of the research was five months.

The main research method is modeling and simulation. The study was conducted in two stages. In the first stage, a new printing cost calculation template was developed using Excel spreadsheet program. The development of the new model is based on existing calculations used in different factories and interviews with the employees. In the second stage, the model was simulated using three imaginary job orders in order to determine the critical parts of the calculation.

To gain more thorough understanding of production processes and current printing cost calculations at factory-level, employees were interviewed. The interviews were unstructured with some questions arranged in advance. This method was chosen because the role of the interviews was to support understanding of existing

calculation templates and the questions varied between the interviewees. Also, I wanted to keep the atmosphere of the interviews conversational and informal, and let the interviewees share their ideas without restrictions. The interviews were held via Skype and documented by taking notes.

This study contains also a literature review on costing and cost control. The literature review focuses on product costing, cost control, and the usage of cost information in decision making. The reviewed literature consists primarily of academic articles, but also standard texts in the field have been reviewed. The selection criteria of the literature were relevance to the industry and to the case, year of publication, and topicality.

1.4 Structure of the thesis

This study consists of two parts: a literature review and an empirical study. The structure is illustrated in Figure 1 as an input process output diagram. The diagram gives a chapter-level demonstration of the information required, how the information is processed, and the results.

The literature review focuses on different product costing practices, cost control and the role of cost information in strategic decision making in the continuous process manufacturing environment and the printing industry. The empirical study is divided to two sections: the definition of printing cost and the development of printing cost calculation model.

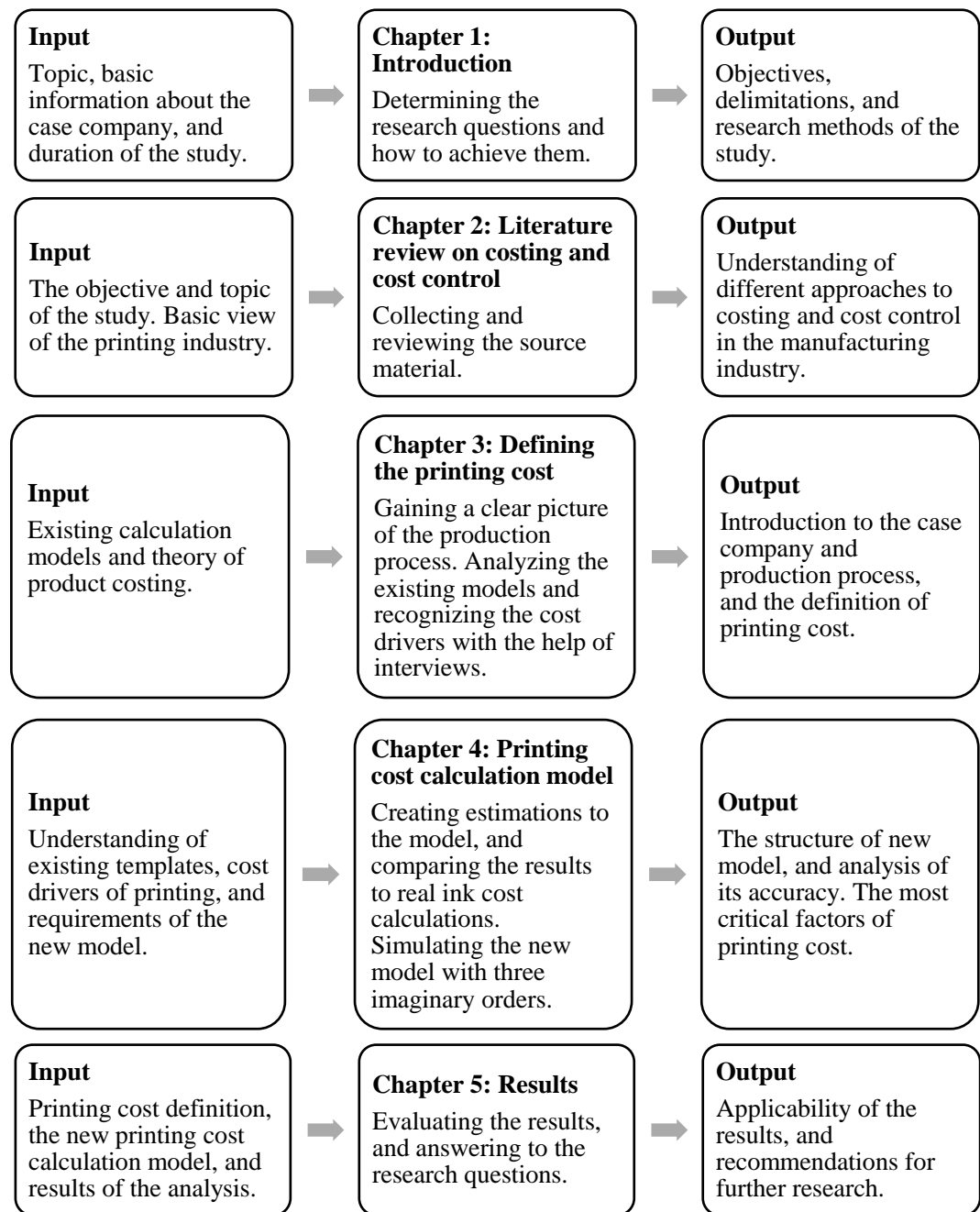


Figure 1. Input process output diagram of the structure

2 LITERATURE REVIEW ON COSTING AND COST CONTROL

Costing is a process for determining the cost of cost objects. The purpose of costing system is to document the costs of resources acquired and track how those resources are used to manufacture and sell a product or service. (Horngren et al. 2012, 30) Costing provides information to understand how the profits and value is created, and how effectively the operational processes transform input into output. It can be applied to any business function, such as products, customers, resources, processes, and channel-related information covering the organization and its value chain. (Professional Accountants in Business Committee 2009, 5)

Costs can be classified into different categories for different purposes. For instance, the categorization of costs may be done according to their management function (manufacturing cost vs. non-manufacturing cost), ease of traceability (direct cost vs. indirect cost), behavior in accordance with activity (variable cost vs. fixed cost), timing of charge against revenue (e.g. product and period cost), and relevance to decision making (e.g. relevant, actual, and standard cost). (Collier 2003; Hansen et al. 2006; Horngren et al. 2012) How these costs are used for different purposes is discussed further in this chapter.

2.1 Product costing

Product costing is widely discussed topic among researchers and practitioners (Brierley et al. 2001; Brierley 2011). The purpose of product costing systems is to allocate direct and indirect costs to products (Horngren et al. 2012, 47). There exists many different costing methods both in the literature and in practice (Professional Accountants in Business Committee 2009, 5). The most commonly used costing systems in manufacturing firms are traditional costing and activity-based costing (Brierley et al. 2001; Brierley et al. 2006; Brierley 2011). The biggest difference between these two costing systems is how the overhead costs are allocated to products (Trigg et al. 1997).

However, the allocation of overhead costs is just one part of product costing. In this chapter, different definitions of product cost, tracking direct costs, and assigning indirect costs to products are discussed. Also, the difference between actual, normal, and standard costing is determined.

Product cost definition

First step in product costing is to decide what to include in product cost. Fisher & Krumviede (2015) emphasizes that one product cost definition cannot meet all costing needs. For example, company may like to use more inclusive definition for pricing decisions than inventory valuation. Any combination of costs can be included in product cost (Fisher & Krumviede 2015) but the purpose of cost information is important criteria when choosing the right cost inclusion (Horngren et al. 2012, 12). Several cost models and the most usual cost inclusions are presented in Figure 2.

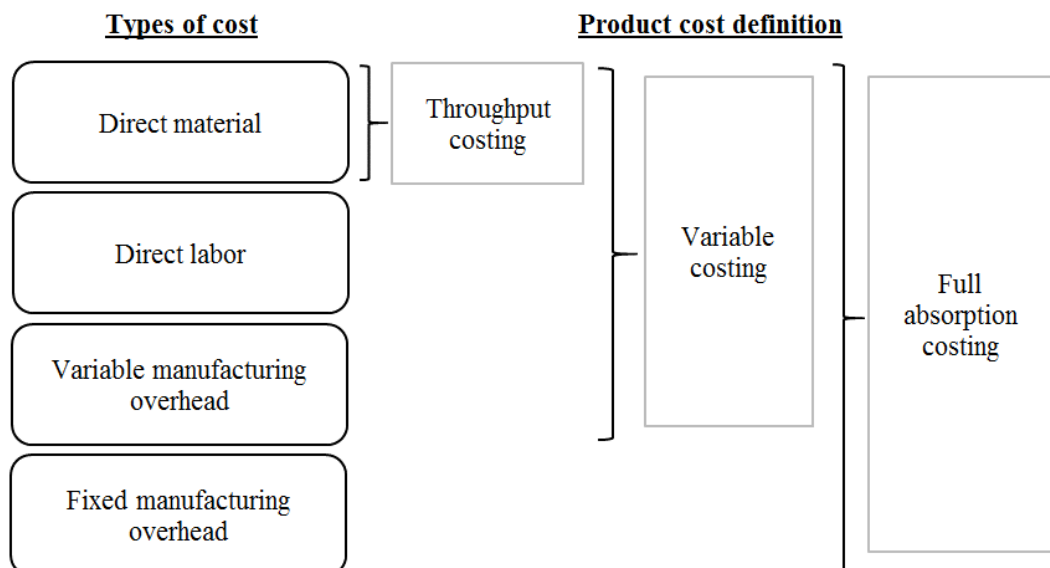


Figure 2. Levels of product costing completeness (based on Fisher & Krumviede 2015)

Throughput costing is relatively simple method because it includes only direct materials as product costs. All the other costs throughput costing treats as period costs. It is consistent with just-in-time production and discourages inventory buildup. However, throughput costing may lead to strategic errors, such as underpricing products, because it does not take any other direct costs or indirect manufacturing related costs into account. (Fisher & Krumviede 2015)

Variable costing treats all variable manufacturing costs as product costs and all fixed costs as period costs (Fisher & Krumviede 2015). The fixed costs must be covered by the products' contribution margins (Hughes & Paulson Gjerde 2003). It classifies costs to variable and fixed. As throughput costing, variable costing may also be misleading for some strategic decisions. For example, some products may have relatively high proportion of fixed costs and using variable costing to determine prices for those may lead to underpricing. (Fisher & Krumviede 2015)

In the literature, full absorption costing often refers to the traditional approach to overhead allocation (Collier et al. 2003; Hansen et al. 2006). Full absorption costing includes all manufacturing costs as product costs and it is the most commonly used in practice. All non-manufacturing costs, such as sales, admin, and distribution, are treated as period costs. The problems of full absorption costing are that it does not include any non-manufacturing costs in product cost, and it may treat fixed manufacturing costs as variable. The amount of non-manufacturing costs can be even more significant than production costs in many companies, and therefore ignoring these costs can provide misleading information for strategic decision making. (Fisher & Krumviede 2015)

Tracking direct costs

Direct costs can be tracked to products using several costing systems, such as job costing, process costing, and operation costing. These practices are often associated with traditional costing systems but they can be applied to activity-based costing also (Cokins & Hicks 2007). Choosing the most appropriate practice requires

understanding of the production environment and products. (Fisher & Krumviede 2015)

When each job or product is unique, job costing is usually the most appropriate method. In job costing, the costs are tracked to individual jobs. Job costing is typically the most accurate costing system because it is the best to capture the unique aspects of each job. However, job costing can lead to unnecessary recordkeeping for costs that are common to all jobs. It is also quite expensive because it requires separate recordkeeping for each job. (Fisher & Krumviede 2015)

Job costing is often contrasted with process costing. Process costing is ideally appropriate for continuous processes where individual units are indistinguishable. It tracks costs by departments and calculates average cost for all units for a time period. Process costing assumes that all products are uniform, and therefore it does not capture unique costs of products. However, it is typically the easiest and the least costly method to use. (Parkinson 2011; Fisher & Krumviede 2015)

Operation costing is a hybrid of job costing and process costing. It captures the unique costs of each job, but tracks the common costs by department and calculates average cost for all units for a time period. For instance, operation costing works well in environments where the products have different materials but go through the same production process. Operation costing is not as accurate as job costing when the jobs differ but it is more cost-effective for costs that are common for each job or unit. Comparing to process costing, operation costing requires more effort. (Fisher & Krumviede 2015)

Organizing and allocating indirect costs to products

The key challenge of product costing is relating to how the indirect costs are organized to products (Fisher & Krumviede 2015). Indirect costs, often referred as overhead costs, are costs that are necessary for producing a product but they cannot be readily traced to cost objects (Collier 2003, 157). Traditional costing sys-

tems organize indirect costs by calculating an overhead rate, and allocate them to products using a production volume-based driver, such as units produced, direct labor hours, or machine hours. (Horngren et al. 2012)

Some companies simplify the first stage in allocation and assignment of overhead costs by calculating a blanket overhead rate, for a factory, a group of factories or a company. The companies use that rate to allocate overhead costs regardless of the production department. It is suitable for assigning overhead costs to products when only one product is produced or all products consume the same amount of resources regardless of the production department. Using blanket overhead rates in multi-product production may cause reporting of distorted product costs. (Drury 2004; Brierley et al. 2005)

Another widely used method is departmental overhead rate, which is more accurate than the blanket overhead rate (Brierley et al. 2005; Fisher & Krumviede 2015). In this method, the overhead rate is calculated individually for each department, such as production department or production and service/support department. In the UK, Drury et al. (1993) noted that companies used two methods to incorporate service and support department costs to product cost. The service/support department cost was included in product cost either using separate service/support overhead rate or the cost was allocated to production department and charged to products using production department overhead rate. (Brierley et al. 2001)

However, prior research argues that the simple plantwide and departmental overhead rates can lead to highly distorted product costs because they include only one cost driver (Fisher & Krumviede 2015). In order to address this issue, Kaplan and Cooper (1987) developed activity-based costing (ABC) approach to calculate product costs. ABC emphasizes the need to gain better understanding of cost behavior and causes of overhead costs (Drury 1989). Job, process, or operation costing systems, that are traditionally used with overhead rates to assign indirect costs,

can be more accurate if they are combined with ABC (Cokins & Hicks 2007).

Figure 3 illustrates the structure of activity-based costing model.

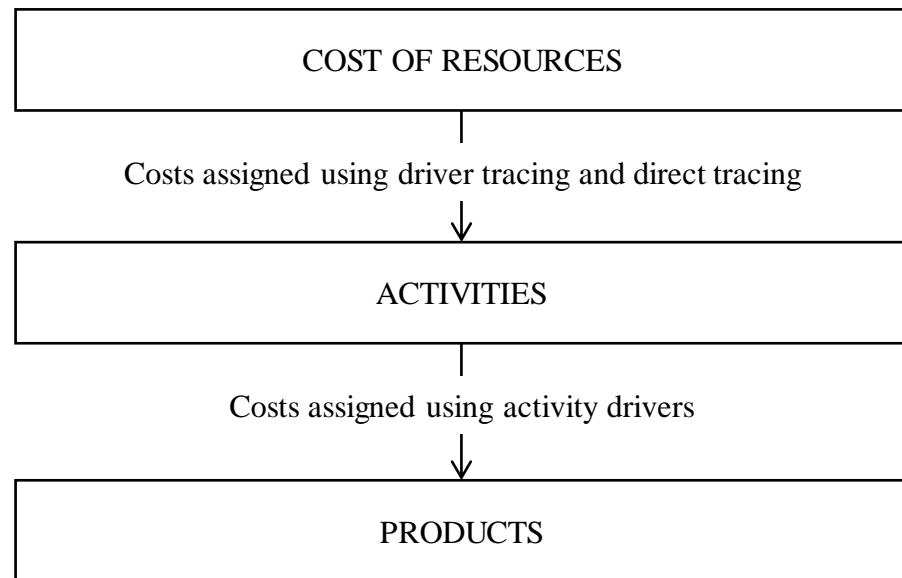


Figure 3. Activity-based costing model (Hansen et al. 2006, 134)

ABC uses cost pools to acquire the costs of business activities and cost drivers to allocate the costs to the activities. The cost pools represent business processes and they are irrespective of the organizational structure of the business. The cost driver for each cost pool is identified based on the most significant cause of cost. As each business has its own activities and circumstances, there are no rules about what cost pools and cost drivers should be used. (Collier 2003, 166-167) For example, the cost pools for prepress and printing could be order processing, plate-making, make-ready, run, clean-up, inspection, and customer service. Suitable cost driver for make-ready could be number of colors, for instance. Cost driver examples for each activities are presented in Figure 4.

Cost pool	Cost driver
<ul style="list-style-type: none"> • Order processing • Platemaking • Make-ready • Run • Clean-up • Inspection • Customer service 	<ul style="list-style-type: none"> • Orders • Plates, sizes, etc. • Number of colors • Sheets, stock, weight, etc. • Plates, press type, colors • Orders • Calls, visits, deliveries

Figure 4. Prepress and printing activities example (Wiersema 1996)

However, ABC has been criticized for the difficulty in collecting activity data, allocation challenges, and high implementation costs among other things. In response to this issue, time-driven ABC (TDABC) has been developed. (Kaplan & Anderson 2007; Fisher et al. 2015) TDABC approach allows the resource demands imposed by each transaction, product, or customer to be estimated directly, instead of assigning the resource costs first to activities and then to products or customers. Only two parameters need to be estimated: the cost per time unit of supplying resource capacity and the unit times of activities. The resource capacity is measured usually in terms of time availability but TDABC recognizes also other capacity units, such as warehouse space. The unit times of activities means how much capacity does one unit of activity consume. For example, how long does it take to process an order. The cost driver rates are then calculated by multiplying these two parameters. (Kaplan & Anderson 2004)

Cost drivers can be based on volume, transaction, duration, or intensity. It is important to choose a cost driver that approximates the cause-and-effect linkage between the costs and the product as accurately as possible. Volume-based drivers are simple and often used with overhead rates. Transaction-based drivers, such as number of setups or purchase orders, are often used with ABC. TDABC uses duration-based drivers that measure the time used for an activity. Intensity-based drivers seek to measure the real resources used by an activity. For instance, inten-

sity-based driver can treat separately hours requiring different human resources. (Fisher & Krumviede 2015)

Brierley et al. (2005) have researched product costing practices in continuous production process environment comparing to discrete-part and assembly manufacturing in the UK. The research was based on three areas identified by Drury and Tayles (1995). The most commonly used allocation and assignment method in both manufacturing environments was production department overhead rates. The second common methods were production and service/support overhead rates and variable costing with similar proportions amongst the operating units. A minority of respondents used blanket overhead rates even though only two of the total of 30 operating units produced a single product. Also, only a few operating units used ABC. The most used overhead rates were machine hour, direct labor hour, and number of units produced. The other commonly used overhead rates were direct labor cost, production time, and material cost.

Actual, normal, and standard costing

Actual, normal and standard costing systems differ in terms of the relevance to decision making, and they are often regarded as traditional management accounting practices (Hansen et al. 2006, 187; Quinn et al. 2013). The differences of actual, normal, and standard product costing are presented in Table 1. Actual costing requires actual costs of all resources to be used for determining the unit costs. Normal costing, however, requires actual costs only to determine direct labor and material. Manufacturing overhead is applied based on predetermined estimate. (Hansen et al. 2006, 187) Standard costing is somewhat different as it uses standard costs for all costs of resources (Quinn et al. 2013).

Table 1. Comparison of actual, normal and standard product costing

	Actual costing	Normal costing	Standard costing
<i>Direct labor</i>	Actual	Actual	Standard
<i>Direct material</i>	Actual	Actual	Standard
<i>Manufacturing overhead</i>	Actual	Budgeted	Standard

Strict actual costing systems are rarely used in practice because accurate unit cost information cannot be provided on a timely basis. Direct labor and material are easy to trace to units produced but using actual manufacturing overhead is a challenge. The three reasons for that are as follows: (Hansen et al. 2006, 187)

1. Traditional system uses unit-level drivers to apply overhead, even though many overhead items cannot be traced to units of production
2. Many overhead costs are not incurred uniformly throughout the year, which can cause overhead costs to differ significantly from one period to the next
3. Seasonal production and non-uniform production levels in general can cause per-unit overhead costs to vary dramatically

ABC overcomes the first difficulty by using multiple cost drivers that are not only unit-level drivers. Product costs can vary periodically due to the second and the third difficulty, even though the products and production process remain the exact same. The problem of fluctuating per-unit overhead costs can be solved by waiting until the end of the year before assigning the overhead costs to products. That is unacceptable though because the product cost information is needed throughout the year. (Hansen et al. 2006, 187)

The problem of actual costing can be solved by normal costing. Instead of using actual manufacturing overhead costs, normal costing measures overhead on a pre-determined basis. The predetermined overhead rate is calculated at the beginning of the year. As the year goes on, the calculated rate is used to apply the overhead costs to products. (Hansen et al. 2006, 187)

Standard costing uses estimates of what it should cost to produce a product under efficient operating conditions (Quinn et al. 2013). These estimates are called standard costs, which are defined by price standards and quantity standards. Price standards specify how much should be paid for the quantity of the input to be used and quantity standards specify how much of the input should be used per unit of output. The definition of standard cost is shown in Equation 1. (Hansen et al. 2006, 383)

$$\textit{Standard cost} = \textit{Standard price} \times \textit{Standard quantity} \quad (1)$$

Establishing the standards often require information from several sources, such as historical experience, engineering studies, and input from operating personnel. Standards can be classified as either ideal or currently attainable. Ideal standards demand maximum efficiency and can be achieved only if everything operates perfectly. Currently attainable standards are demanding but achievable – they can be achieved under efficient operating conditions but allowances, for example, to normal breakdowns, interruptions, and less than perfect skill are made. (Hansen et al. 2006, 383)

At the end of the period, standard costs are compared to the actual costs to evaluate performance. (Quinn et al. 2013) Standard costing operates the best in repetitive business processes, as the inputs and related costs should be accurately determined and close to the actual costs (Johnson & Kaplan 1987; Quinn et al. 2013). An inaccurate standard costing system may lead to misguided decisions on product pricing, product sourcing, and product mix, for example. (Johnson & Kaplan 1987)

2.2 Cost control

Information from accounting systems helps to manage costs but the information and accounting systems are not cost management themselves (Horngren et al.

2012, 4). In the literature, the management accounting term control refers to the set of procedures, tools, performance measures, systems, and incentives that are used to motivate and guide all employees to achieve organizational goals (Ștefea & Niță 2012). Collier (2003, 240) defines cost control as a process of either reducing costs while maintaining the same level of productivity or maintaining costs while increasing productivity. Cost management encompasses the continuous process from beginning-of-period planning to end-of-period performance evaluation (Kren 2008).

Reviewing business processes

Collier (2003, 240) discusses that cost control can be exercised by undertaking a review of horizontal business processes. That can be achieved, for example, crossing organizational boundaries, rather than carrying out the review within the traditional hierarchical structure of an organization chart. The objective is to find out what activities people are carrying out, why they are carrying out those activities, and whether they need to be carried out after all, and whether there is more efficient method of achieving the desired output. In relation to most costs, the questions that can be asked are:

- What is being done?
- Why is it being done?
- When is it being done?
- Where is it being done?
- How is it being done?

In flexographic printing process, there is many opportunities to control costs by investigating and improving the working methods. Every press and printing process are somewhat different, but the documented steps and standard operation procedures can be developed. For example, while the previous job is still running, the ink can be brought to the press, the components, such as mounted cylinders, gears and bearings can be checked for wear, and viscosity and pH (for water-

based inks) can be measured to make sure they are within recommended ranges. Before the run, the color, viscosity and pH should be double checked and it is important to make sure that the ink settings are at their minimum. As the printing progresses, any essential information should be documented so that the job can be run efficiently again the next time. The objective is to maintain high quality while minimizing the duration of a press run. (Utschig 2000)

Understanding the cost drivers

To lead cost control efforts, managers have to understand the activities of the company. Managers cannot manage costs directly – instead, they are managing the activities that cause costs. (Kren 2008) Therefore, understanding the causes of costs, the cost drivers, is important for achieving cost improvements. The information on the costs of activities and the cost drivers can be provided directly by ABC systems. (Collier 2003, 240)

Activity-based management (ABM) is a process of activity analysis, presented by Kaplan and Cooper (1998). Kaplan and Cooper (1998, 137) describes ABM as “the entire set of actions that can be taken, on a better informed basis, with activity-based costing”. Companies can increase their productivity by achieving the same outcomes at lower spending on organizational resources with ABM. ABM is differentiated to operational and strategic.

Operational ABM refers to the actions required to do things right, such as actions that increase efficiency, lower costs, and improve asset utilization. It aims to meet the organizational demand with fewer organizational resources, either by increasing the capacity or by lowering the spending of resources. Reduced costs and higher revenues through better resource utilization can be achieved by operational ABM. Also, the benefits can be measured by cost avoidance because the need for additional investments in capital and people are obviated by the expanded capacity of existing resources. (Kaplan & Cooper 1998, 137)

Strategic ABM aims to alter the demand for activities to increase the profitability while assuming that the efficiency of activities remain constant. It works by shifting the unprofitable activities into profitable ones by reducing the cost driver quantities demanded. (Kaplan & Cooper 1998, 137–138) Strategic ABM encompasses the decisions made about pricing, product mix, customer relationships, supplier relationships, product design, and product development. (Kaplan & Cooper 1998, 160)

Even though ABM has been initially developed to support ABC systems, it can be an useful tool to understand and control costs in any organization. With ABM, organizations can get clear signals to identify specific actions needed for cost management. These signals are often lacking in a traditional cost management environment. For example, ABM can be used to provide information for cost management as follows: (Kren 2008)

1. During planning, to identify and manage non-value added activities (costs) and excess capacity in activity inputs
2. During the period, to set performance improvement targets based on elimination of non-value added activities and associated costs
3. At the period end, to provide clear signals about the actions needed for cost control and capacity management by variances

The traditional approach to cost management proposes that operations managers have direct control over spending in their area of responsibility. Traditional accounting reports fail to provide cost management insights for operations managers because they show only general ledger line items. Especially, the end-of-period variances traditional accounting systems provide are not usually informative enough for operations managers to evaluate performance and recognize opportunities for improvement. (Kren 2008)

Standard costing

Standard costing has been widely used tool of cost control since early 1900s (Fleischman & Tyson 1998; De Zoysa & Herath 2007), and it still continues to be a popular management accounting practice (Quinn et al. 2013). However, many academics have questioned the relevance of standard costing to modern manufacturing (Johnson & Kaplan 1987; Quinn et al. 2013). For instance, cost structure, just-in-time (JIT) production, and flexible business processes are some of the modern organization characteristics that have been argued to be incongruent with standard costing (Johnson & Kaplan 1987; Quinn et al. 2013).

As already mentioned in Chapter 2.1, standard costing systems aim to improve performance measurement in addition to planning and control (Hansen et al. 2006, 384). Standard costing highlights the difference between the planned costs and the actual costs of the period (Mitchell 2005). Computing variances is an important part of budgetary control systems also (Collier 2003, 225; Hansen et al. 2006, 384). Standard costing, however, provides a broader view to the causes of variances by dividing the total variance to price variance and efficiency variance. (Hansen et al. 2006, 384) The formulas of these variances are presented in Equations 2 and 3. (Hansen et al. 2006, 388-389)

$$\text{Price variance} = \left(\text{Actual price} - \text{Standard price} \right) \times \text{Actual quantity} \quad (2)$$

$$\text{Efficiency variance} = \left(\text{Actual quantity} - \text{Standard quantity} \right) \times \text{Standard price} \quad (3)$$

After the variances have been computed, the causes of them should be interpreted. A favorable variance occurs when the actual prices or actual quantity of inputs used are less than standard prices or quantities. Unfavorable variance works as opposite: the actual prices and the usage of inputs are greater than standards. (Hansen et al. 2006, 388) Cost variance comprises several different elements that are demonstrated in Figure 5. (Mitchell 2005)

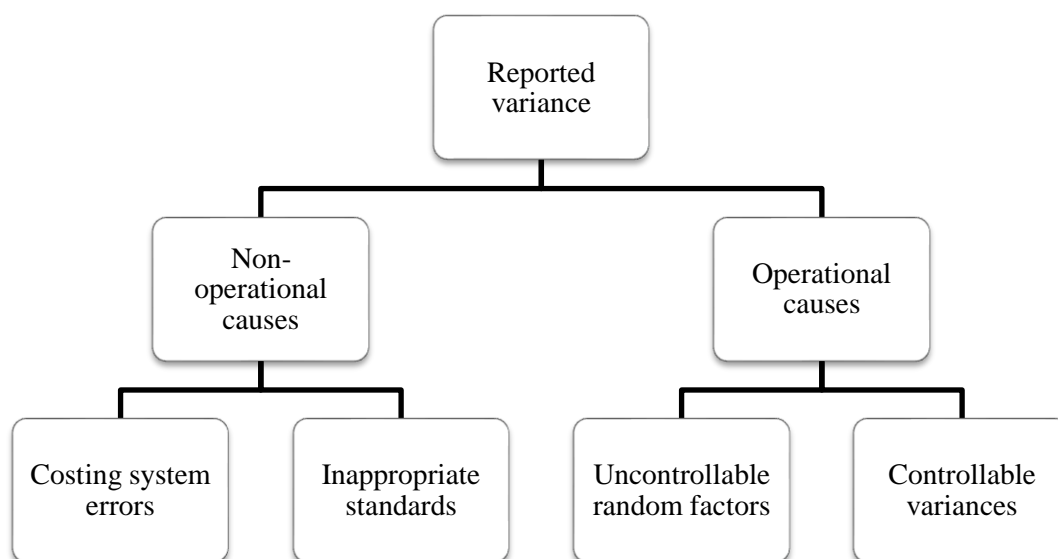


Figure 5. Elements of cost variance (Mitchell 2005)

Mitchell (2005) suggests that the causes of cost variance can be divided to non-operational and operational. Non-operational causes relate to the problems in the administration of standard costing systems. Errors in the costing systems, such as inaccurate direct labor time recording, may cause wrongly reported variances. Also, the standards set into the system have a direct effect on the variances. For example, the standards may be set tightly in order to motivate the employees to increase performance. These unattainable standards cause variance that might not need corrective actions to be taken. Alternatively, the standards should always represent the current situation, and standards that are set some time ago might become obsolete if they have not been revised recently.

Operational causes are related to operational activities, such as purchasing and use of resources. The elements under operational causes are uncontrollable random factors and controllable variances. Works containing human involvement will most likely cause uncontrollable variance because human performance lacks consistency. This inevitable and therefore uncontrollable variance is not a signal of actions needed. The variance that managers can influence is the controllable variance with operational causes. For example, new working methods as well as ma-

chine faults can be causes of variance that managers are able to control. (Mitchell 2005)

The challenge of variance analysis is that there are usually more than one element causing the variance. Also, the causes of variances might not have clear causal relationships. For instance, the material price variance may be caused by a sudden change of material supplier or payment terms. That is the reason why the variances should be interpreted with care. It is important to eliminate the chance of problems in the standard costing system before looking for the causes from operations. (Mitchell 2005)

2.3 Decision making using cost information

The need of decision making apply to every operation in an organization (Professional Accountants in Business Committee 2009). According to Kaplan & Cooper (1998, 1), leading companies use the information from cost systems as follows:

- To design products and services that at the same time meet the customers' expectations and yield a profit
- To signal where either continuous or discontinuous (re-engineering) improvements in quality, efficiency, and speed are needed
- To assist the employees in their learning and continuous improvement activities
- To guide product mix and investment decisions
- To choose among alternative suppliers
- To negotiate about price, product features, quality, delivery, and service with customers
- To structure efficient and effective distribution and service processes to targeted market and customer segments

Cost information is valuable for performance improvement, value creation, “what if” analysis, and effective and efficient application of resources and processes. However, using same cost information in decision making and financial reporting may lead to misunderstandings. Financial reporting uses cost information to the valuation of inventories, the determination of transfer pricing amounts, and segmental reporting, for example. These uses of costs are usually mandated by jurisdictions and regulatory authorities, whereas managerial decision making often require deeper insights into the causes of events, clear and direct connect to operations, and support to planning for desired future outcomes. (Professional Accountants in Business Committee 2009, 5) Collier (2003, 147) argues that the lack of cost information in relation to business processes is a limitation of traditional accounting systems, many of which are initially developed to support financial reporting primarily.

Many decision making situations focus on how to influence the future events. Therefore, past performance needs to be reviewed in the light of recent and expected new developments, even though it may give hints on what will happen in the future. The cost data prepared for decision support must be thus valid for the particular purpose. External financial reporting use mainly historical cost data, which is normally non-causal in nature. The cost information used to support managerial decisions can be more effective if the information is based on clear and timely link between the causes and effects. (Professional Accountants in Business Committee 2009, 15)

Also, Kaplan & Cooper (1998, 2) argue that only one costing system is not enough to perform the primary functions of cost systems. These three functions are (1) the valuation of inventory and the measurement of the cost of goods sold for financial reporting, (2) estimation of the costs of activities, products, services, and customers, and (3) providing economic feedback to managers and operators about process efficiency. Professional Accountants in the Business Committee (2009, 7) show cost measurement as embracing three broad areas: cost account-

ing, performance evaluation and analysis, and planning and decision support (Figure 6).

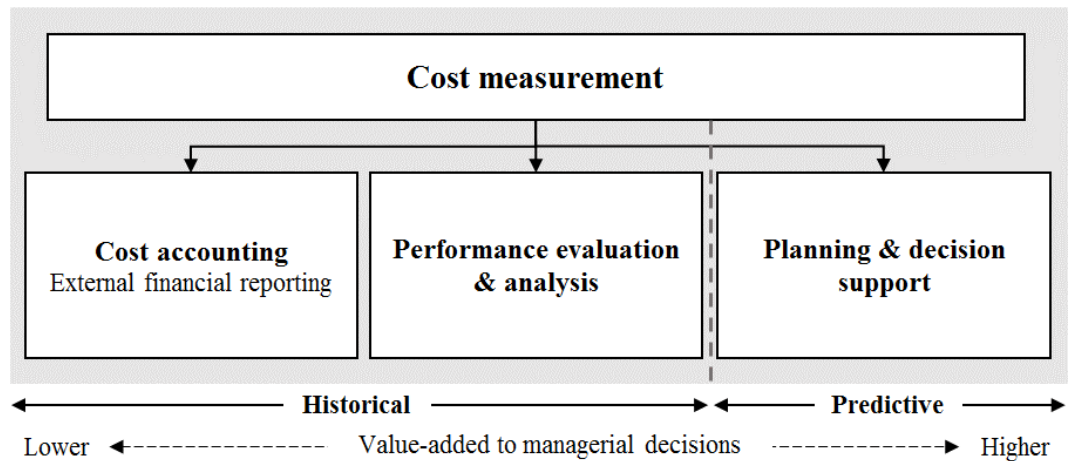


Figure 6. Cost measurement as embracing three broad areas (based on Professional Accountants in the Business Committee 2009, 7)

Cost accounting is prescribed by standards for financial accounting (e.g. IFRS and GAAP) because it is used for external reporting, such as inventory valuation and cost of goods sold. The other two areas, performance evaluation and analysis, and planning and decision support are generally more value-adding for management accounting. Performance evaluation and analysis focus on historical cost data, which is used, for example, for assessing current strategy and plans, profitability reporting, process analysis, learning and corrective actions, and to evaluate integrated cost and operational performance measures. Planning and decision support require predictive cost information for fully absorbed and incremental costing, adaptive operation and cost-based planning, budgeting, and forecasting, strategic adaptations of product process, channels and customers, and enterprise optimization decisions (e.g. make vs. buy, outsourcing), for example. As managerial decisions mainly focus on the future, predictive cost information provides higher amount of value to managerial decisions than historical information. (Professional Accountants in the Business Committee 2009, 6-7)

Cokins and Hicks (2007) emphasize that to make sound, fact-based decisions, using accurate and relevant cost information is critical. That means that the calculated costs are a reasonable estimate of the economic facts of a situation or a cost objective being measured. Also, the type of costs and resource expenses calculated should be appropriate for the decision at hand.

According to Cokins and Hicks (2007), the three basic types of relevant costs are fully absorbed cost information, incremental cost information, and activity or process cost information. Fully absorbed costs are needed to support strategic decisions, such as pricing decisions to understand profit margins. They must be measurable at varying volumes and mixes of business activity. Incremental costs are the difference in total expenses between two alternatives in a decision. Activity and process costs help the business isolate the costs of critical business processes and activities that can be used to guide and measure its continuous improvement, mass customization, supply chain management, and lean thinking initiatives.

The development of management accounting information consists of two factors: the model and the data. The model represents the cost and effect economic relationships whereas the data represents the actual or projected quantification of the organization's cost drivers, driver/activity/cost relationships, distribution, and so on. A properly designed model should be able to process any scenario to quantify its results in monetary terms. From a particular perspective, any model may seem to be an universal solution to all management accounting problems but if that perspective differs, the solution appears totally inappropriate. (Cokins & Hicks 2007)

3 DEFINING THE PRINTING COST

3.1 Introduction to the case company

The case company operates globally in the packaging industry and it employs about 1000 people. Products of the company are mostly customer-specified and produced in a continuous process manufacturing environment. The product prices are determined to each customer order individually depending on product specification, order quantity, and annual volume.

3.2 Production process

The first step to evaluate the cost factors of printing was to understand how the end product is manufactured and what is the role of printing in the whole manufacturing process. In order to reach this goal, one factory was visited and the employees of the company were interviewed.

Three manufacturing options of end products were taken into account in this study. Figure 7 illustrates simply the manufacturing processes of printed products. The material can be printed before or after the extrusion process, or it can be only printed. After extrusion and printing the order is packed for warehousing and transportation but that process is not analyzed further in this study. Also, finishing (e.g. sheeting) may be one part of the whole production process.

Extrusion means that metal or plastic is forced through a die to create the desired shape. Extrusion laminating allows materials, such as aluminum and paper, to be combined. In extrusion coating, a layer of plastic is melted on top of paper, board, aluminum foil, cellulose or plastic films. During the extrusion process, the raw material, usually paper, is extrusion laminated or coated.

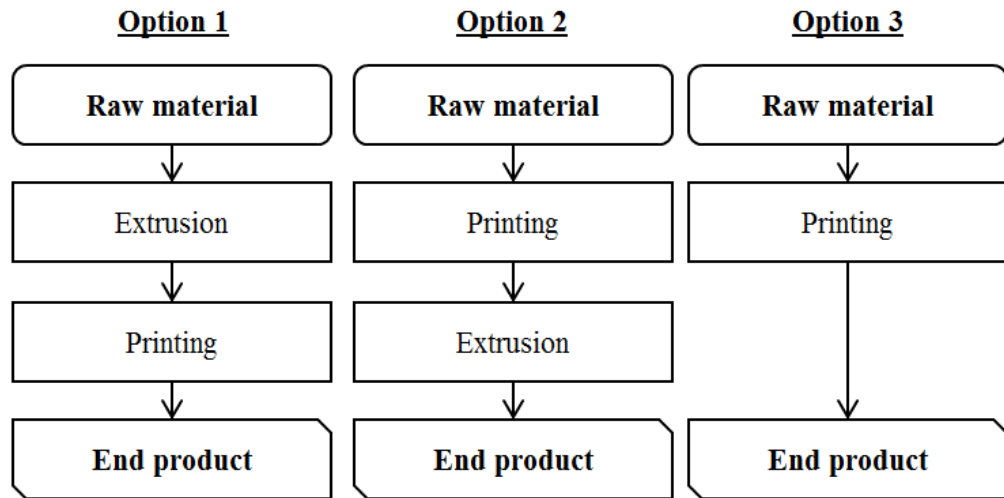


Figure 7. Manufacturing options of printed products

Printing is any process that transfers to paper or another material an image from an original, such as plate (Printing Industry Exchange 2018). In flexographic printing process, the image is carried to the substrate by printing plates. Printing plates are made based on the design for each color separately. A printing plate function so that the image area is raised above the non-printing area, and the ink is transferred to the above raised area by an anilox roller. Anilox is a method used to transfer a measured amount of ink to the printing plate. This process is illustrated in Figure 8.

The anilox roll is a hard, usually ceramic cylinder that has millions of very fine dimples, known as cells, on the surface. The quantity of cells determines how much ink it transfers to the printing plate. In this paper, the term anilox transfer is used to define the ink transfer in g/m^2 . During the printing process about 40-60% of the theoretical anilox transfer really transfers to the image.

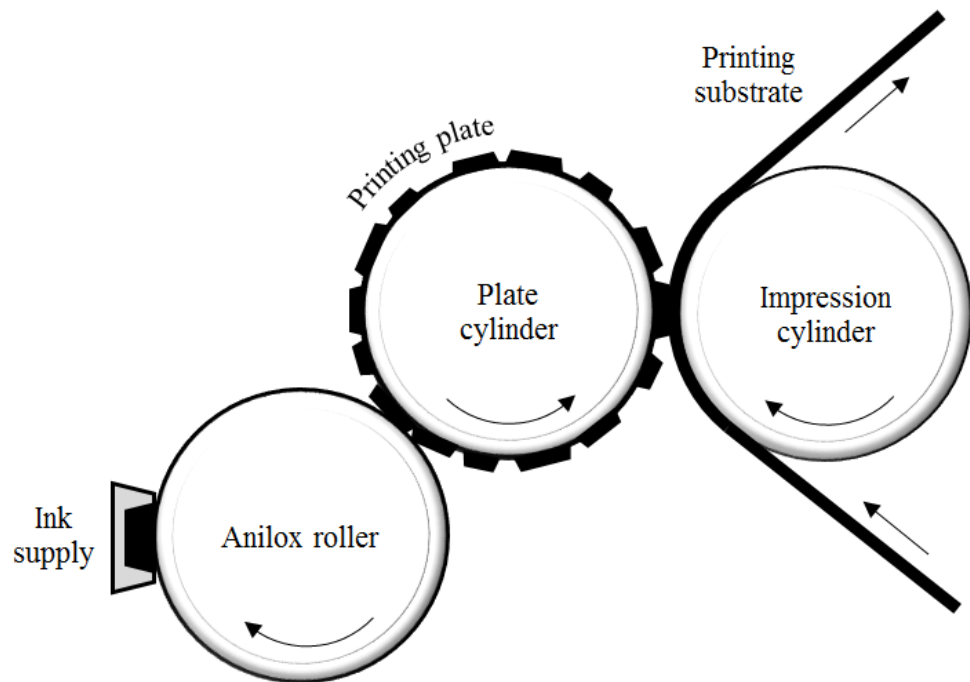


Figure 8. Simplified illustration of flexographic printing process

The inks are mixtures of base colors and other components, such as additives and extenders. The proportions of different components vary depending on for example, the shades of colors, the printing machine, and the product. As the base colors determine the end color, the extenders and additives give the ink the properties needed. The basic color palette includes cyan, magenta, yellow, and black. Examples of other base pigments are white, green, orange, and violet. The base pigments can be mixed into grey, brown, and beige, for example.

In the case company, the number of colors used vary between one to ten. The inks are mixed before printing, and ready-made inks are installed to the machine. The number of colors also affects the amount of waste material because during the start-up a certain amount of substrate must be scrapped due to the set-up of colors. The total waste ink occurring in the process (during set-up and clean-up) is about 10-20 kilograms per color depending on the production quantity. The amount of waste ink is influenced by production planning though. For example, if all the

jobs of a certain machine use the same inks, the waste ink is much less, almost none, because there is no machine clean-up needed between the runs.

The total machine time consists of set-up and run. The start-up duration of a printing machine depends on the number of colors of the image. The machine speed depends on many factors, such as machine, product, and design of the printing image. For example, the running speed of one machine may vary between 100-400 m/min.

3.3 Findings from the existing printing cost calculations

The case company had at least five existing spreadsheet models in use in the pricing process of printed products: a group-level product pricing model including only the extrusion phase, and factory-level models for printing cost calculation. The printing cost was calculated separately using different models, and then the result was added to the common product pricing model. The product pricing model was updated once a year, but the updates of factory-level models were not followed by the group management.

For printing cost calculation, there was several spreadsheet models in use. The existing models were used in different factories and countries, and even some of the employees had their own calculation templates. In this study, two of these existing models are examined. The models chosen were used in two different factories, and they had the most potential to be developed. The models consisted of similar components but differed from their default values, calculation methods, and other features.

To fully understand the existing models, two employees of Factory A and one employee of Factory B were interviewed. The interviewees were asked to describe how their model are used currently at their site and what are the most critical parts in the printing cost calculation. The models and interviewees by facility are presented in Table 2.

Table 2. Models and interviewees by facility

Facility	Model	Interviewees	Department of interviewee
<i>Factory A</i>	Model A	Interviewee A Interviewee B	Finance Technical development
<i>Factory B</i>	Model B	Interviewee C	Production

The features of existing printing cost models are concluded in Table 3. Both models consisted of four major cost factors: machining, ink, and waste. Also, the models had several other factors affecting the cost, such as rewinding, printing plates, and prepress.

Table 3. Comparison of the existing printing cost calculations

	MODEL A	MODEL B
Production		
<i>Duration</i>	Set-up, run	Set-up, clean-up, run
<i>Machine hour rate</i>	Inserted manually case-by-case	Average value defined depending on machine
Material: Ink and lacquer		
<i>Ink coverage</i>	Total ink coverage	Screen coverage and line coverage defined separately
<i>Ink usage</i>	Average value depending on printing side	Average anilox transfer depending on the product type
<i>Ink price</i>	Average value based on 80% coverage	Average value depending on the mixture of ink
<i>Lacquer coverage</i>	Estimated by ink coverage	Always 90% if lacquered
<i>Lacquer usage</i>	Average value depending on printing side	Fixed anilox transfer
<i>Lacquer price</i>	Average value based on 80% coverage	Average value depending on the lacquer type
Waste	Paper	Color
Other costs	Rewinding, printing plates	Prepress

Machine operating cost was basically calculated similarly in both models. The biggest difference was in the calculation of duration. Model A consisted of only

set-up and production run duration but Model B included also clean-up duration. Set-up duration of Model A was divided to the machine set-up and set-up trim.

In both models production run duration was calculated based on machine speed. In Model A, machine speed could be defined manually case-by-case but in Model B, it was only possible to use machine average speed. Interviewee A (2018) said that the most mistakes are done when choosing the machine speed. There can be huge differences between machines and the speed is dependent on product and order dimensions. Also, Interviewee C (2018) supported the fact that the machine speed is highly contingent on the product type and the printing design. Nevertheless, in Model B the machine speed was only depending on the machine. According to the Interviewee A (2018), choosing the right machine speed requires in the most cases production manager's consultancy.

In Model B, machine hour rates were included in the model and brought automatically to the calculation by choosing the machine. In Model A, the field was open and the rates were brought manually from another table to the calculation. Machine hour rates are calculated once a year at group-level. Automating this field would minimize typos that may result misleading calculations. Also, updating same information to multiple places will always expose to mistakes, and it is more challenging to follow if timely information is used in every calculation.

Ink cost was calculated differently in the models. Both models used estimated values, but for some cases, Factory A used real values calculated by technical development. In Model A, the ink cost calculation was based on the average ink cost of 80% ink coverage. Interviewee A (2018) said it is not accurate way to determine ink cost and the best way would be to let technical development to calculate the real value for each case. However, Interviewee B (2018) specialized in printing inks thought that the ink cost could be calculated accurately enough using estimations. The inks, extenders and lacquers could be categorized by price and a matrix could be created based on that categorization according to Interviewee B (2018).

In Model B, the ink cost was determined by choosing the mixture of ink from an option field which brought the category price of the mixture automatically to the calculation. Interviewee C (2018) questioned if this is accurate way to calculate the cost. At least, the list of category prices should be updated because the categories of current list were ambiguous according to the users. After understanding the real ink cost calculation, it appeared that the calculation method in the Model B were incorrect. The calculation method computed the ink cost as there were always two colors used. Therefore, it is reasonable to suspect that the ink cost was computed on the low side in many cases.

The determination of ink usage also differed between the models. In Model A, the usage of ink was very roughly estimated by choosing the printing side. In Model B, the calculation was based on screen and line anilox values that were looked up from a table by selecting the product type. Interviewee C (2018) said that the current product type list in the Model B included only a part of products so the user should know which product is similar to other in order to choose correct anilox transfer. In the new model, the basic ink usage calculation should be based on anilox values like in Model B according to Interviewee B (2018). Interviewee B (2018) also thought that the anilox transfers cannot be categorized by products. Better method would be to categorize them by colors.

In both models, the definition of coverage was a visual rough estimate. In Model A, only total coverage of ink was possible to define. In Model B, screen and line coverages could be defined separately. Interviewee C (2018) was concerned about what is the best way to define ink coverage: the visual rough estimation method or as determined technically by the designer of image. In reality, the colors can be printed one on the other and therefore the coverages are determined by color, not by image.

The basic idea of **lacquer cost** calculation was similar to ink cost in both models. In Model A, the estimation of lacquer coverage was based on the ink coverage.

Interviewee A (2018) thought that the current method was not accurate and there should be possible to define the lacquer coverage manually like the ink coverage was in the model. Also, printing side affected the usage of lacquer. The lacquer price was estimated similarly as the ink price, based on average lacquer cost of 80% coverage. In Model B, the coverage of lacquer was estimated as 90% and the price depended on selected lacquer type. Interviewee C (2018) said that the lacquer coverage varies between 90-100% in reality and it should be possible to choose the coverage between that interval. The anilox transfer was determined as 5,3 g/m² even though it varies between products.

There was some differences in the **waste** calculation between the models. Model A included only start-up waste paper, but not at all the waste ink. However, Interviewee B (2018) confirmed that the total waste ink is taken into account when calculating the real ink cost at Factory A. Model B included start-up waste ink but not the waste paper, even though the waste ink calculation was based on the amount of waste paper. Also, the ink left in the pipes and cleaned up after the production run were not included in the Model B.

There were also **other cost factors** related to printing found in the models. Model A included costs of rewinding and printing plates. Interviewee A (2018) told that both factors are important for the calculation. Rewinding percentage of the order depends on the machine and the job itself. At Factory A, printing plates are usually replaced once a year. The fixed cost of printing plate was allocated to the printing cost using annual volume as a cost driver. In Model B, prepress costs included printing plate and other activities done before the final printing. It was only used if sales manager requested however. Usually, printing plates were not included in the printing cost calculation.

The calculation of printing cost appeared to be quite complicated and strongly dependent on machine, product, and order dimensions. Neither of the models were fully suitable for all cases. Model B was too simplified but its usability was better than Model A's. Model A had more variables affecting the cost than Model B and

Model A also let more accurate values to be used for some variables. Some jobs require more specific calculations than estimations can afford. That had to be taken into account in the development of new model. However, estimated values can be quite accurate for some basic products and using them had to be also possible in the model.

4 PRINTING COST CALCULATION MODEL

Both existing printing cost calculations had their pros and cons and thus the new model was influenced by both of them. The aim was to develop a model that can be used for all products at all factories. The main users of the model are sales managers that do not always have such a deep understanding of the production process and the technical specifications of the products. Therefore, the new model had to be simple and easy to use.

Because the real printing cost, especially the ink cost, is relatively complex to calculate, some rough estimations were necessary. Some variables, such as machine speed could not be estimated however. Therefore, the template was also seen as an opportunity to enhance the cooperation and communication between sales department and production plants. It was important to know during the creation of the model even though the implementation of the model is excluded from this thesis.

After evaluating the existing models and discussions with the employees, the development process of the new model went as follows:

1. Construction of the first version based on the comparison of existing models and interviews
2. Testing the printing cost calculation with several designs and comparing them to the real ink cost calculations
3. Reviewing the first version with the interviewees and conducting corrective actions
4. Simulating the model together with the employees of the company
5. Final evaluation of the model together with the interviewees

The case company wanted to keep the new printing cost calculation spreadsheet template confidential. For that reason, screenshots of the template or absolute costs are not presented in this thesis.

4.1 Printing cost calculation

The printing cost consists of production cost, material cost (printing substrate and ink), and waste. The costing method of the case company resembles job costing because the orders are produced according to a customer's specifications. Both fixed and variable overhead costs are allocated to products by machine hours.

Understanding the cost drivers of printing helped the creation of calculation formulas for the model. Figure 9 presents the production cost drivers and the material cost drivers of printing.

Production cost drivers	Material cost drivers
<ul style="list-style-type: none"> • Order quantity • Grammage of substrate • Trimming width • Printing machine • Number of colors • Machine speed • Rewinding percentage • Rewinding speed 	<ul style="list-style-type: none"> • Order quantity • Printing substrate • Printing inks • Printing machine • Number of colors • Anilox transfer • Ink coverage • Edge trim

Figure 9. Printing cost drivers

The machine hours include the duration of set-up, run, and possible rewinding. Run duration is the order quantity in running meters divided by machine speed. Rewinding duration is calculated similarly but the rewinding quantity might be just a part of the whole order quantity. The calculation of machine hours is shown in Equation 4.

$$Machine\ hours = Set-up + \frac{Order\ quantity}{Machine\ speed} + \frac{Rewinding\ quantity}{Rewinding\ speed} \quad (4)$$

The machine operating cost is the machine hour rate multiplied by the total duration (Equation 5). Machine hour rate is calculated machine-level and it contains

both variable and fixed operating costs, such as direct and indirect labor, energy, order handling, and fixed machine overheads.

$$\text{Machine operating cost} = \text{Machine hour rate} \times \text{Machine hours} \quad (5)$$

Direct materials include the printing substrate, such as paper or laminate, and the ink. The cost of printing substrate is calculated by multiplying the material price by order quantity (Equation 6).

$$\text{Substrate cost} = \text{Order quantity} \times \text{Substrate price} \quad (6)$$

Ink cost calculation is presented in Equation 7, where n represents the number of colors. Ink price is the price of ready-made ink, including base colors, extender, and additives. The amount of ink transfer depends on the machine and anilox roll used.

$$\text{Ink cost} = \text{Order quantity} \times \sum_{n=1} \text{Price}_n \times \text{Coverage}_n \times \text{Ink transfer}_n \quad (7)$$

One method to calculate the color prices using spreadsheet program is presented in Figure 10. As the figure illustrates, colors are mixtures of several components and the proportions have a lot of variation. Consequently, the end color prices are weighted averages of the component prices.

Component	Price	Color 1	Color 2	Color 3	Color 4	Lacquer
Base color 1	2,50			28 %		
Base color 2	4,30	50 %				
Base color 3	4,50		50 %			
Base color 4	5,50		8 %	4 %		
Base color 5	9,00			31 %		
Base color 6	7,00				100 %	
Extender	4,00	50 %	42 %	37 %		
Lacquer	2,30					100 %
End color price		4,15	4,37	5,19	7,00	2,30

Figure 10. Calculation example of color prices

The waste material cost is simply calculated by multiplying the material price by the quantity of waste (Equation 8). This formula applies to both waste ink and waste paper (or other substrate).

$$\text{Waste cost} = \text{Material price} \times \text{Waste quantity} \quad (8)$$

The waste material is important part of the calculation because the set-up and clean-up of ink always produce unavoidable waste. The more colors the printing job uses, the more waste ink and waste paper are produced. Also, edge trimming might cause production of waste paper.

4.2 Structure of the new model

The new model was built in such a way that there is as few fields as possible that are required to be filled in. The aim was to use standards for every value that could be estimated accurately enough. When comparing to the existing models, the biggest developments were made to the ink cost calculation. To avoid resistance to change among the users, the layout of the model was created similar as in the existing pricing template.

Production cost

The production cost consists of direct and indirect labor, and variable and fixed manufacturing overhead. The costs are tracked to jobs by machine hours.

Table 4 presents the inputs that are needed to calculate the production cost in the new spreadsheet template.

Table 4. Inputs to calculate production cost

Input	Function
Order quantity	To express order quantity in kilograms
Grammage of substrate	To express order quantity in square meters
Printing machine	To determine the machine hour rate, and the set-up time
Trimming width	To express the quantity produced in running meters
Machine speed	To calculate the run time
Number of colors	To determine the set-up time

The machine hour rates by printing machines are saved on the file and brought into the calculation by selecting the printing machine. Also, the set-up times and the set-up trims by number of colors are standards that depend on the printing machine. The machine speed has a high variation among the products so it was not possible to define an estimation for it. Therefore, its value must be defined case-by-case.

An important thing to notice is also that the trimming width means the width in which the order is produced, not the width in which it is sold to the customer. Orders can be slit to the final width during or after the run to save run time. The run time is calculated based on the production running meters.

The production cost section has also several optional fields that may be used if needed. Rewinding percentage and rewinding speed determine the duration of rewinding which is included in the total production time. The need of rewinding depends on the mill, the machine, and the product itself. Also, the set-up time and set-up trim can be defined manually for special jobs.

Direct material cost

The direct material cost consists of the cost of ink used and the cost of waste. In order to simplify the ink cost calculation, the colors, lacquers, and extenders were classified into price categories. The color categories are CMYK, standard colors, and special colors. White ink was decided to be not included in these categories because it can be used as a backing color with 90-100% coverage. The category prices were defined separately for each mill because the prices of components differ between them. The inputs of the ink cost calculation is presented in Table 5.

Table 5. Inputs to calculate ink cost

Input	Function
Number of CMYK	To determine how many CMYK colors are used
Number of standard colors	To determine how many standard colors are used
Number of special colors	To determine how many special colors are used
Usage of white ink	To determine if white ink is used or not
Lacquer	To determine which lacquer is used
Extender	To determine the extender used
Coverage	To determine the ink usage. Separate fields for screen ink, line ink, special colors, white ink, and lacquer

In the calculation, it is assumed that the base color is mixed with the extender in proportion 1:1. Basically, the end color price is calculated as the average of the color category price and the extender category price. It would have been too complicated for the users to select every color component and their proportion individually. The machine ink transfer percentage was estimated as 40% in the template.

The most challenging part of the ink cost calculation was to define the anilox transfer. The anilox has an huge impact on the ink usage but it is a variable that is hard to be defined by the users of the template. It is highly dependent on the prod-

uct, and the ranges by colors can vary a lot between the product types and mills. In the new model, it was decided to determine the anilox transfers by color categories. It appeared to be the most accurate method in this case. The anilox transfer ranges used in Factory A and Factory B are shown in Table 6. Also, the estimate determined to the template is presented in the table.

Table 6. Anilox transfer ranges in g/m^2

	Factory A	Factory B	<i>Estimate</i>
CMYK	5,5–5,6	3,5–7,5	5,5
Other colors	5,5–8,0	7,0–12,0	8,0
Lacquer	5,0	4,5–5,5	5,0

In Factory B, much broader anilox transfer ranges are used than in Factory A. The greatest difference is in other colors. The estimates were determined so that they would be as accurate as possible for both mills. However, it is clear that the estimates will be more accurate for Factory A or at least the costs are most likely not computed on the low side.

Therefore, it was reasonable to analyze what is the effect of anilox transfer on the ink cost in Factory B. Two cases were tested with bottom line anilox transfers and with top line anilox transfers. The minimum and maximum ink cost values were compared to the ink cost at default anilox transfers. Both of the test cases had an order quantity of 5 tons and grammage of $120 g/m^2$. The cases are two usual color combinations in the product portfolio of the case company (Table 7).

Table 7. Cases to test the effect of anilox transfer on the ink cost in Factory B

	Case A: 2 colors	Case B: 6 colors + lacquer
<i>Colors</i>	1 CMYK, 5% coverage 1 Standard, 10% coverage	4 CMYK, 20% coverage 1 Standard, 5 % coverage 1 Special, 5% coverage
<i>Lacquer</i>	No lacquer	100% coverage

When all the anilox transfers are less than estimated, the model computes the ink cost higher than it really is. That is not eligible situation of course but in the case of pricing calculation it is more important to ensure that the products are not underpriced. While all the anilox transfers are higher than estimated, the model computes lower ink cost than it should. Table 8 shows the minimum and maximum anilox transfers used.

Table 8. Minimum and maximum possible anilox transfers in g/m² in Factory B

	Minimum	Maximum	Default (estimate)
<i>CMYK</i>	3,5	7,5	5,5
<i>Standard color</i>	7,0	12,0	8,0
<i>Special color</i>	7,0	12,0	8,0
<i>Lacquer</i>	4,5	5,5	5,0

The test was conducted using the new printing cost calculation model by changing the estimated values of anilox transfer. The results are demonstrated in Figure 11.

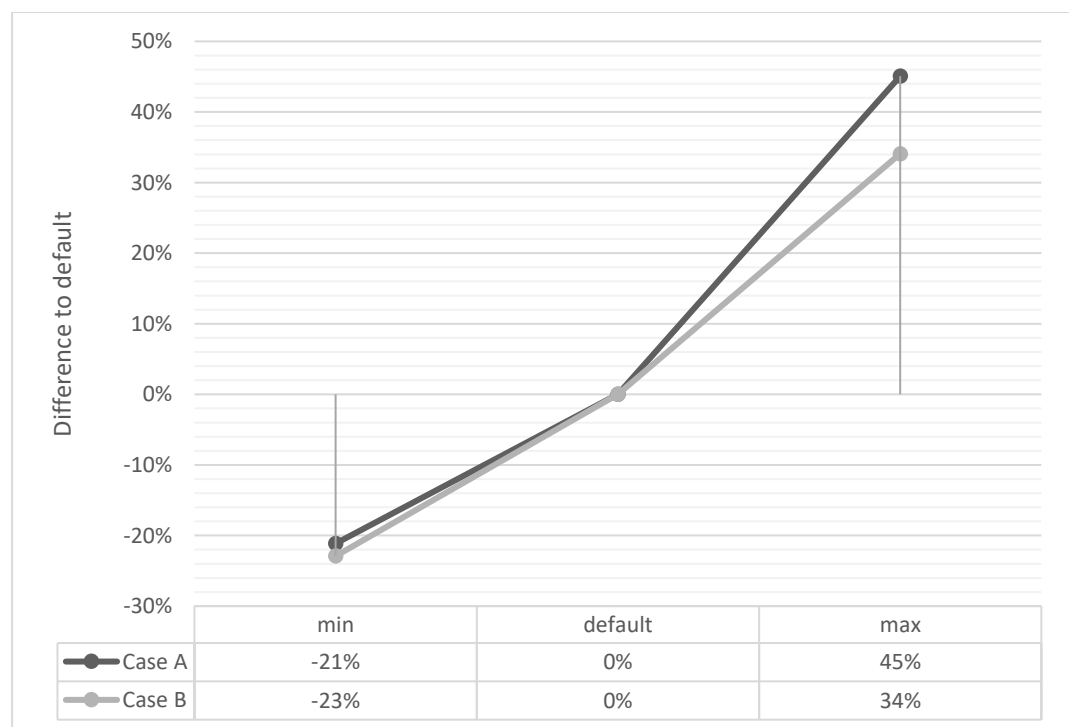


Figure 11. The effect of anilox transfer on the ink cost in Factory B

It is clear that the anilox transfer has an significant effect on the ink cost. Also, the difference is not directly proportional with the number of colors. That is reasonable because the anilox transfer is not the only variable affecting the ink usage. Another significant factor of the ink usage is the coverage of ink. However, these results give very rough view of the effect on the ink cost because it is unlikely that the lowest or highest anilox transfers are used for every color of any printing job. Also, the anilox transfers can vary within a color category so even though the anilox transfers could be modified in the template, some kind of average should be defined. In this point, the estimates were decided to be kept this way but it might be reasonable to evaluate them again later.

The last part of direct material cost is the waste material. It includes the waste substrate and the waste ink. The inputs affecting waste cost calculation are shown in Table 9.

Table 9. Inputs to calculate waste

Input	Function
Printing machine Number of colors	To determine the waste caused by set-up trim
Edge trim	To determine the waste caused by edge trim
Price of substrate	To determine the cost of waste substrate
Colors used	To determine the cost of waste ink

The set-up waste was possible to estimate by the printing machine and the number of colors. Some orders require edge trimming due to the width of raw material, for example, so the width of edge trim will automatically calculate the quantity of waste based on the production running meters. The cost of waste substrate is highly contingent on the price of material printed. For that reason, it is important to take into account if the material is first printed and then extruded or the other way round.

The calculation of waste ink is based on the selected colors and an average amount of waste ink. The standard waste ink per color was determined as 5 kilograms. The waste ink depends strongly on the production plan and the product portfolio of the machine. If the machine requires full clean-up after the printing run, the amount of waste is usually 10-20 kilograms per color. If multiple jobs using the same colors are printed sequentially, the waste ink produced might be almost none. This estimation is based on the production crew's consultancy.

4.3 Accuracy of the ink cost calculation

The ink cost calculation part of the new printing cost calculation model required use of many estimations. The new model was tested with several real ink cost calculations of different designs produced in Factory A. As already mentioned in Chapter 4.2, the anilox transfer estimations should work well for the products of Factory A. Therefore, these cases were selected for comparison to test if the new ink cost calculation method itself is accurate.

The test cases are presented in Table 1. The order dimensions, such as order quantity and grammage were same in all test situations. The calculation includes the cost of waste ink that is 10 kg/color in the real ink cost calculations and 5 kg/color in the new model. The machine ink transfer percentage used was 50% in the real ink cost calculation and 40% in the new model.

Table 10. Case designs to test the accuracy of ink cost calculation

Design	Colors and lacquer	Coverages
Design A 2 colors	1 CMYK 1 Standard color No lacquer	5% screen coverage 10% line coverage
Design B 5 colors + lacquer	1 CMYK 2 Standard colors 2 Special colors Lacquer	12% screen coverage 40% line coverage 32% special color coverage 93% lacquer coverage
Design C 7 colors + lacquer	4 CMYK 3 Standard colors Lacquer	16 % screen coverage 12% line coverage 93% lacquer coverage
Design D 3 colors + lacquer	1 CMYK 2 Standard colors Lacquer	80% screen coverage 6% line coverage 93% lacquer coverage
Design E 5 colors + lacquer	1 CMYK 4 Standard colors Lacquer	4% screen coverage 4% line coverage 94% lacquer coverage
Design F 4 colors + lacquer	4 CMYK Lacquer	80% line coverage 94% lacquer coverage
Design G 6 colors + lacquer	3 CMYK 3 Standard colors Lacquer	14% screen coverage 12% line coverage 93% lacquer coverage
Design H 2 colors + lacquer	1 CMYK 1 Standard color Lacquer	35% screen coverage 93% lacquer coverage

The results are illustrated in Figure 12. Even though the quantity of waste ink and machine ink transfer (causing higher usage of ink) were greater in the real ink cost calculation than in the new model, the new model gave higher ink costs for almost all of the test designs. The average difference to the real ink cost was 22% based on this test.

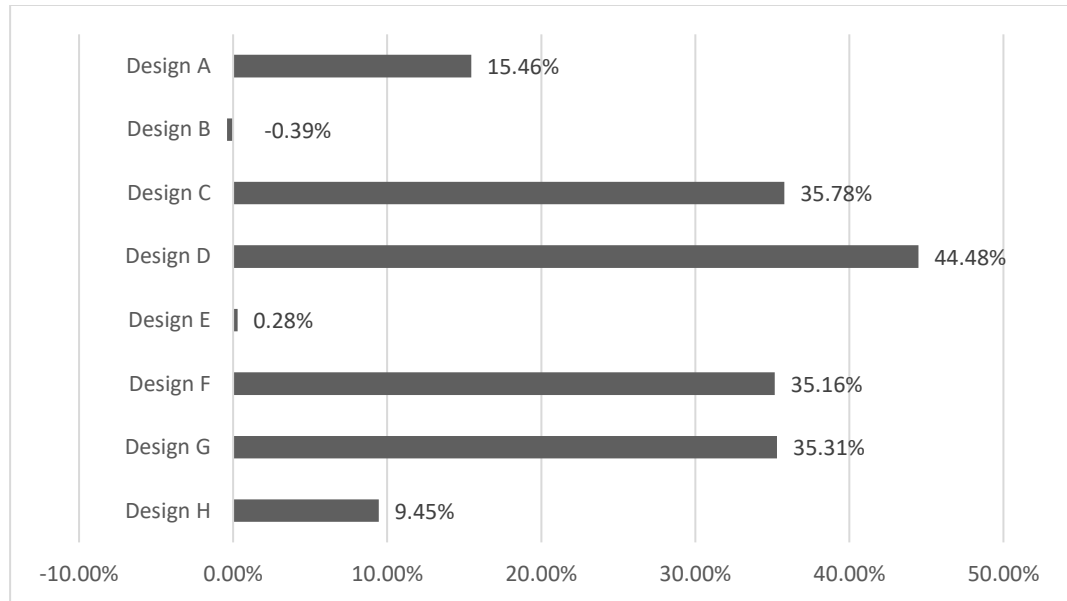


Figure 12. Difference of new model's ink cost to the real ink cost

Higher ink coverage does not automatically mean more inaccurate result. For example, the total ink coverage of Design A is 15% and Design H's is 35%. However, the difference of Design A's ink cost to the real ink cost is approximately 6 percentage units higher than Design H's ink cost difference. Also, the number of colors does not have direct relation to the difference. For example, Design B has 5 colors and its difference to the real cost is negative. Design D has 3 colors and its difference is about 44% positive. Design C has 7 colors, more than Design B, but its difference is about 36% positive.

By taking deeper look into the individual colors, it appeared that the biggest reason for difference was the difference between the average color category prices and the real ink prices. There are some colors, the real price of which is below the category average. However, for some special colors the situation is the opposite – the real ink price is higher than the category average.

4.4 Printing cost simulation

The new printing cost calculation model was simulated with three imaginary customer orders. The orders were built up to resemble typical customer orders of the case company. The objective of this testing is to illustrate the results of the model and recognize the most critical parts of the printing cost calculation.

Table 11. Imaginary customer orders

	Order A	Order B	Order C
Quantity [kg]	5 000	10 000	20 000
Grammage [g/m ²]	110	110	110
Width [mm]	800	1000	1200
Machine speed [mm]	200	240	300
Number of CMYK colors	4	4	0
Number of standard colors	0	3	1
Number of special colors	0	0	1
Lacquer	Yes	Yes	No
Extender	Basic	Expensive	Cheap
Screen coverage	30%	50%	20%
Line coverage	10%	30%	0%
Special color coverage	0%	0%	10%
Lacquer coverage	90%	90%	0%

It was assumed that the orders are manufactured at the same printing machine. Therefore, the same, made-up machine hour rate is used in all three calculations. The set-up time and the set-up waste vary between the orders depending on the total number of colors. Also, the printing substrate used in all orders is the same so the grammage and the price of substrate do not vary between the orders. Because none of the orders are edge trimmed during printing the waste substrate is compounded only of the set-up trim.

Printing cost calculation of Order A

Order A is the smallest and the narrowest of the orders. Also, its run speed is the lowest. Its print contains the standard colors of CMYK color model, lacquer, and

mid-range extender. The coverage of each color is 10% and the lacquer coverage is 90%. The printing cost is illustrated in Figure 13.

I. PRODUCTION		II. MATERIAL	
Order [kg]	5 000	Cost of standard colors [EUR]	558,00
Grammage [g/m ²]	110	Cost of special colors [EUR]	0,00
Order [m ²]	45 455	Cost of lacquer [EUR]	163,64
Production run	56 818	Total ink cost [EUR]	721,64
Machine speed [m/min]	200	Set-up trim [m]	230
Run time [h]	4,73	Waste substrate [m ²]	184
Set-up time [h]	1,25	Waste substrate cost [EUR]	16,19
Total time [h]	5,98	Waste ink per color [kg]	5
Machine hour rate [EUR/h]	210,00	Waste ink cost [EUR]	79,75
Production cost [EUR]	1 256,82	Total waste cost [EUR]	95,94
Printing cost [EUR]:	2 074,40		
Printing cost [EUR/ton]	414,88		

Figure 13. Printing cost calculation of Order A

The biggest factors affecting production cost are the machine hours and the machine hour rate. Because the machine hour rate do not vary between the orders compared the examination can be focused on the machine hours. The machine hours compound of run time and set-up. The run time depends on the quantity produced and the machine speed. The number of colors to be set-up determine the set-up time.

The second part of the calculation is the material. The material costs are defined by the print design and the ink components. The CMYK is the most typical color model used in color printing so Order A resembles very typical four-color printing image.

The waste cost is directly proportional with the number of colors, but also the inks used have an huge effect on it. The waste percentage is the higher the smaller the order size is because the quantity of set-up waste is a fixed value. The breakdown of Order A's printing cost is illustrated in Figure 14.

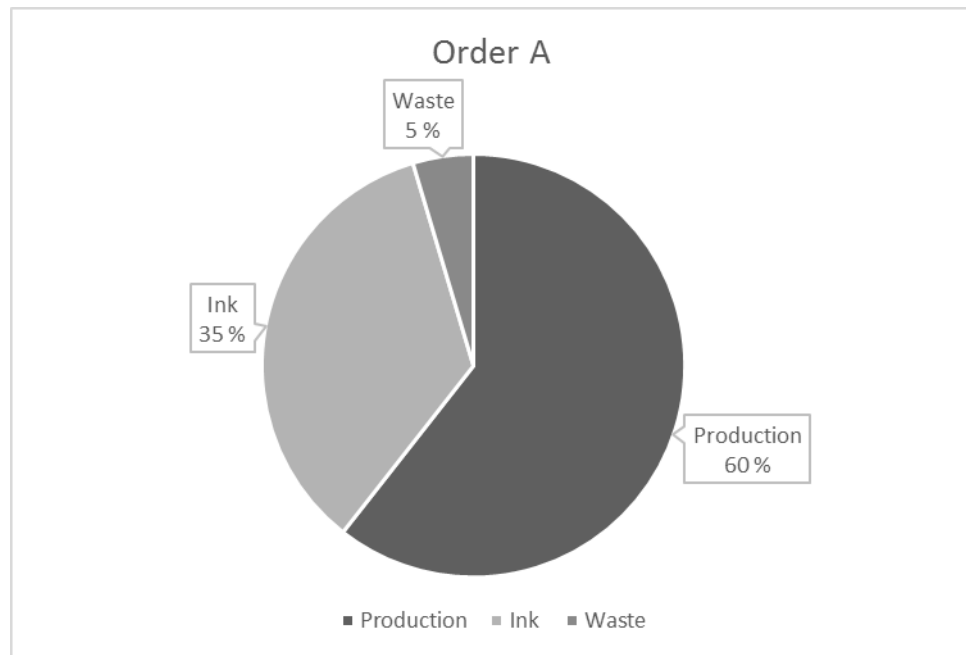


Figure 14. Printing cost breakdown of Order A

The production cost has the greatest share of the total costs with 60% proportion. The share of ink is 35% and the share of waste 5%. The share of production costs could be less if the order can be run at a higher speed or on wider machine two customer widths in parallel.

Printing cost calculation of Order B

Order B resembles a typical color combination and coverage when the image has larger number of colors. It has the most complicated print design of the three orders and also, the total coverage of ink is relatively high. Additionally, the extender used in this printing is the most expensive one. Therefore, it is reasonable to assume that the material costs of this order will be relatively high.

The order quantity of Order B is two times higher than Order A's so the production will probably last longer than the production of Order A. The width of Order B is wider than Order A's and also, the order is run at a higher speed. That will have a reducing impact on the run time. However, the number of colors increase the time consumed in set-up.

The complexity of the printing image can be seen in the printing cost calculation of Order B (Figure 15). As it was expected, the total ink cost of this job is relatively high. The effect of the greater number of colors is seen at the waste cost too. It affects both the cost of waste substrate and the cost of waste ink. The production costs are in line with the order quantity when compared to Order A.

I. PRODUCTION		II. MATERIAL	
Order [kg]	10 000	Cost of standard colors [EUR]	6 198,55
Grammage [g/m ²]	110	Cost of special colors [EUR]	0,00
Order [m ²]	90 909	Cost of lacquer [EUR]	327,27
Production rm	90 909	Total ink cost [EUR]	6 525,82
Machine speed [m/min]	240	Set-up trim [m]	410
Run time [h]	6,31	Waste substrate [m ²]	410
Set-up time [h]	2,00	Waste substrate cost [EUR]	36,08
Total time [h]	8,31	Waste ink per color [kg]	5
Machine hour rate [EUR/h]	210,00	Waste ink cost [EUR]	169,66
Machining cost [EUR]	1 745,76	Total waste cost [EUR]	205,74
Printing cost [EUR]:	8 477,32		
Printing cost [EUR/ton]	847,73		

Figure 15. Printing cost calculation of Order B

The share of ink is about 77% of the total printing cost (Figure 16). That leaves only 21% share for production cost and 2% for waste cost. The breakdown is very different when compared to the cost breakdown of Order A.

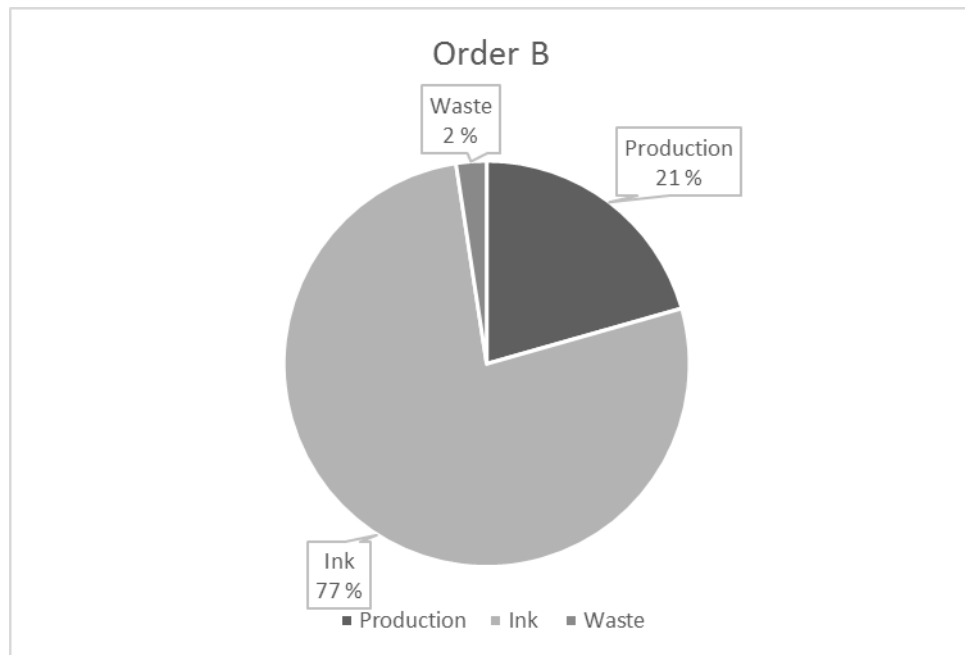


Figure 16. Printing cost breakdown of Order B

The ink cost is almost impossible to be reduced without changing the printing image or the ink components. The best way to reduce the costs of this kind of job is to focus on the production costs and the run time. For example, the set-up time and waste can be reduced by efficient production planning. A wider printing machine and higher run speed would be effective cost reduction possibilities in this case too.

Printing cost calculation of Order C

Order C is the largest of the orders but its printing image is the simplest. It resembles typical two-color print. Even though one of the colors belongs to expensive special color category, it can be supposed that the material costs will not be significantly high because the total number of colors is few, the extender used is cheap, and there is no lacquer used.

Because the size of Order C is four times higher than Order A's and two times higher than Order B's the run time of Order C is most likely the longest. Howev-

er, this order is run at the highest speed and also, the set-up time is the shortest. The width of Order C is also wider than other orders’.

The cost calculation of Order C (Figure 17) proves these assumptions true. The production costs are in line with the other orders. Due to higher run speed, wider product width, and shorter set-up time the total machine hours are close to Order B’s even though Order C is two times larger than Order B by size.

I. PRODUCTION		II. MATERIAL	
Order [kg]	20 000	Cost of standard colors [EUR]	406,55
Grammage [g/m ²]	110	Cost of special colors [EUR]	526,55
Order [m ²]	181 818	Cost of lacquer [EUR]	0,00
Production rm	151 515	Total ink cost [EUR]	933,09
Machine speed [m/min]	300	Set-up trim [m]	50
Run time [h]	8,42	Waste substrate [m ²]	60
Set-up time [h]	0,50	Waste substrate cost [EUR]	5,28
Total time [h]	8,92	Waste ink per color [kg]	5
Machine hour rate [EUR/h]	210,00	Waste ink cost [EUR]	62,72
Production cost [EUR]	1 872,68	Total waste cost [EUR]	68,00
Printing cost [EUR]:	2 873,77		
Printing cost [EUR/ton]	143,69		

Figure 17. Printing cost calculation of Order C

The cost breakdown of Order C (Figure 18) is similar to the cost breakdown of Order A. Production costs have the largest share with 65% whereas the share of ink is about 33%. The share of waste is only 2% that can be explained by few number of colors and large order quantity.

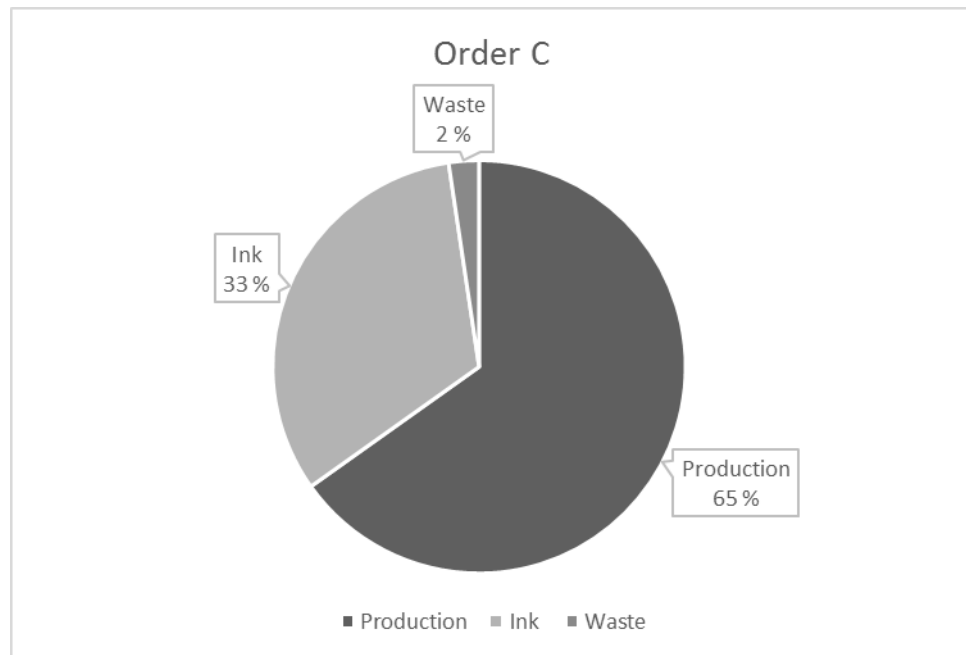


Figure 18. Printing cost breakdown of Order C

The printing cost per ton of Order C is the lowest of the orders. It is the most efficiently produced when considering the order quantity and the machine speed. Also, the material costs of Order C are relatively low due to low number of colors and cheap extender.

Results of the simulation

The results of the simulation are concluded in Table 12. It is obvious that the order quantity is not directly proportional with the total cost of printing. Based on this simulation, the most critical parts of printing cost calculation are total machine hours and number of colors.

Table 12. Results of the printing cost simulation

	Order A	Order B	Order C
Job order quantity	5 tons	10 tons	20 tons
Total machine hours	5,98 h	8,31 h	8,92 h
Number of colors (incl. lacquer)	5	8	2
Production cost	1 256,82 €	1 745,76 €	1 872,68 €
Ink cost	721,64 €	6 525,82 €	933,09 €
Waste cost	95,94 €	205,74 €	68,00 €
Total cost of printing	2 074,40 €	8 477,32 €	2 873,77 €
Printing cost per ton	414,88 €	847,73 €	143,69 €

The job with the largest number of colors (Order B) is the most expensive when considering the printing cost per ton. Its ink cost is high due to large number of colors. Order C is the cheapest and it also has the lowest number of colors. Order A is mid-range by both the number of colors and the printing cost. The printing cost per ton can be reduced by larger order quantities. Generally, it is more cost efficient to produce large quantities of same product.

The printing cost per ton seems to be in line with the number of colors. In addition to ink cost, the number of colors have an indirect impact on the production cost. The number of colors affect the set-up time and also, the machine speed depends on the printing image. Because both the number of colors and the total machine hours are highly contingent on the printing image, it can be concluded that the printing image is a significant factor of the printing cost.

4.5 Comparison of results with previous research

The availability of research related particularly to the cost of flexographic printing is limited. The research focuses mainly on comparing different costing methods and controlling the costs of printing operation (Wiersema 1996; Utschig 2000).

Findings concerning the cost drivers of printing were in line with the drivers that were found in this study.

Hinkkanen (2018) has analyzed the cost structures of production machines in the packaging industry. Her study resulted that the machine lines with the highest running speeds caused less costs. Machine speed has a direct impact on the production time that affects the production costs especially when a machine hour rate method is used to allocate overhead costs. Also, the cost control efforts presented by Utschig (2000) focus on reducing the production time by efficient working methods during the whole printing process.

Wiersema (1996) has illustrated the fact that the cost breakdowns of complex and routine printing jobs are different. A complex printing job with high number of colors requires more time for set-up and clean-up operations than a routine job. However, his research assumes that the material cost of a complex order is lower than a routine order's. Also, he has not commented on the difference between order quantities of those two orders. Based on this information, it is hard to make further conclusions about the difference of cost breakdowns of a complex and a routine printing job.

5 DISCUSSION AND CONCLUSIONS

Based on the results the new printing cost calculation model is working well and the persons included in the testing phase were happy with the outcome of this project. Already, it can be said that the new model will improve the pricing process, ensure timely cost information is used, and thus enhance the profitability of customers and products.

Recognizing the cost drivers of printing is necessary for cost control. In case the product costs are higher or lower than expected, understanding the cost drivers helps managers to look for reasons for it. The cost drivers helped also to understand the structure of cost calculation model.

The simulation of printing cost resulted that the printing image has a significant impact on the total cost of printing. Because the products are customer-specified this supports the fact that the products as well as product costs are unique. Structuring a cost calculation model for this purpose was complex because the model was supposed to be simple to use at the same time. However, with carefully established standards it was possible to reach this goal and develop a model that is close to the real cost calculation.

The most important factor affecting the accuracy of the template is how it is used. While testing the model, I had the real design formulations available and I was able to use quite exact values in the new model. The users of the model may not know all the technical specifications of the products they are pricing. Therefore, the new model was also seen as an opportunity to enhance the communication between sales and production departments. This depends however on how the implementation is handled and communicated to the users.

It is possible that some changes must be conducted to the model during the implementation because the implementation of the model is not examined on this study. To avoid this, as many persons as possible were involved to development of the model in the beginning of this project. The fact that the final version will be

used at six factories in total but the analysis was focused on two factories increases the risk for needing to conduct changes later. The risk should be minimal because the two factories in focus have the highest volume of printing operation and much wider product portfolios than the other factories that will be using the model. The risk for late changes could have been minimized by larger test group too but the time available for this project was limited.

An interesting question concerning the development of this kind of models is how the model will be maintained. An easy maintainability was kept in mind during this whole project. It was important to develop a template that can be maintained even by a person that have not been involved in its development. Every field that will require regular updates were formatted by a specified color. The need for touching any formulas when updating the template was avoided. Also, how the data was gathered were documented during the project.

Because the research was conducted to response the needs of a single case company, it is challenging to generalize the results. However, the printing cost definition and the calculation model may be applied to other flexographic printing businesses too. In this case, the uniqueness of products, the knowledge of users, and the number of production facilities set limits for the cost calculation model. The basic cost components of printing are supposedly very similar in every flexographic printing process after all.

For example, if all products experience the same production process or use the same raw materials, such as printing inks, there is no need to make as much estimations as in this case in order to keep the model simple. Also, if the users of the model understand the exact technical specifications of the products, the model may be kept closer to the real printing cost calculation. The less production facilities need to be taken into account, the easier it is to determine the estimations for the calculation model.

A spreadsheet program is not probably the most agile platform for a pricing model that is used by multiple users and for multiple orders. Most of the information needed in the calculation is stored somewhere in the company systems but now the information must be concluded manually into the calculation from multiple sources. Additionally, as the Excel model is updated once a year in this case, the users have to transfer the data from the old version to the new one also once a year. And this has to be done for every job order individually.

A system that saves the previous calculations in a database, for example, would not only save valuable working time but also make sure that everyone is really using the latest version in the pricing decision making. A spreadsheet-based model is however a good starting point for this kind of development project because all the formulas and information needed are already known and evaluated.

6 SUMMARY

The objective of this study was to develop a printing cost calculation model for a case company. Reaching this objective required a visit to one production facility, interviews with the employees, and analyzation of the existing printing cost calculation models of the company.

The first research question was to define the printing cost. The printing cost consists of two major parts: production cost and material cost. Production cost includes direct and indirect labor, and other manufacturing overheads. The overhead costs were allocated to jobs using machine hours. The machine hour rates were calculated at machine-level once a year. The material cost include the costs of printing substrate, printing inks, and waste. Starting up the machine produces always unavoidable waste that depends on the number of colors used and the printing machine. Because the set-up waste is not depending on the job order size, it is more efficient to have long production runs of same product.

The second question to answer was how to structure a printing cost calculation model. The calculation of printing cost appeared to be relatively complex. The technical knowledge of the users of the model limited the development of the new model. Keeping the model simple and easy to use required estimation of several values, especially for the ink cost calculation. The new model was tested with several cases and compared to the real cost calculations. The results of the model were quite close to the real cost calculation even though some values were estimated.

The third research question was to recognize the most critical parts of the printing cost calculation. The new model was simulated with three imaginary job orders in order to reach this objective. The simulation resulted that the printing image has a significant impact on the total cost of printing. It affects obviously the material cost but also the production cost and the waste production.

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