Foreword

The background to this thesis for the degree of licentiate of technology on the topic of customised information on packaging lies in the interesting issues that have arisen from the development of digital printing technologies. Digital printing could have a major effect on how packaging meets new market demands and logistic requirements. The thesis is based on three published papers which are included. The analysis section refers to the different papers and it might be advantageous to read the papers first for the specific details.

I have an academic background consisting of a master's degree in Industrial Engineering and Management from Linköping University focusing on logistics and computer science. This background, together with new insights into media technology, digital printing technologies, and opportunities for marketing using variable data, have given me a platform of logistics, marketing, and digital printing knowledge relevant for this work. Hence, this thesis work does not originate solely in one discipline. Digital printing technology, logistics and marketing aspects are all included. The research has been conducted at my employer STFI-Packforsk and supervised by professor Nils Enlund, Media Technology and Graphic Arts at the Royal Institute of Technology (KTH). The project is part of the regional EU-funded research program "Development of the Digital Printing Community, DP-COM", in Örnsköldsvik and of the national print research program T2F.

I would like to express my gratefulness to the persons that have been supporting me during my work; my inspiring supervisor Nils Enlund for all his support; Marianne Klaman, who has supported my project from the very beginning and has given me the necessary resources within DP-COM; Christian Persson for his valuable feedback in the beginning of my research; my T2F-tutor Lars Palm for comments and interesting discussions; Chris Dominic and Carl Olsmats for inspiring discussions and valuable comments during the compiling of my research into this licentiate thesis. Furthermore, I like to warmly thank all participating case study companies for their kindness, courtesy and cooperation during my work. I also like to thank Per Jonsson and Astrid Odeberg Glasenapp, for introducing me to the T2F-network, that has been a source for inspiration and a good platform for networking. I would also like to express special thanks to my colleagues (all included) at STFI-Packforsk and at the Digital Printing Center in Örnsköldsvik, for their friendship, inspiration and helpfulness. The financial support from the Swedish national research program T2F and the EU are gratefully acknowledged.

Abstract

This thesis work is divided into two parts that relate to each other. The first part investigates driving forces and limiting factors in the customisation of information on packaging and the second part focuses on how the customisation task should be performed in order to obtain high productivity and efficient logistics. Opportunities with hybrid printing solutions where conventional technology is combined with digital printing are discussed.

The first of the included papers talks about the driving forces and limiting factors in the customisation of information on packaging and focuses on marketing aspects and consumer value. The second paper investigates the logistical aspects of using digital printing to add information on pre-printed packaging, with the primary focus on the opportunities to reduce changeover time and printing form costs. The third paper investigates how digital printing can be integrated into a packaging line and identifies critical productivity related parameters. These three papers are analysed together in this report, giving input to conclusions about the driving forces and limiting factors in the customisation of information on packaging and how the customisation task should be performed to obtain high productivity and efficient logistics. Hence, this thesis work does not originate solely in one discipline. Digital printing technology, logistics and marketing aspects are all considered to draw conclusions.

It is shown that it is possible to obtain marketing advantages, fulfill market demands better, get increased consumer value and reduced costs by using a hybrid printing solution. There exists at the same time a number of limiting factors, such as print quality demands, additional costs and reliability issues that are crucial to consider before concluding whether or not customisation of information on packaging would be successful in any given business scenario.

Different scenarios for where the customisation task can be inserted into a value chain are defined and discussed. Explicit studies of one of the scenarios are made. This scenario is defined as having a customisation task inline in a packaging line. The other scenarios, customisation at the packaging producer and customisation at the wholesaler/retailer, are not explicitly investigated, but it has been possible to discuss these scenarios as well through the research results obtained. The results show that there are factors that point towards the scenario where digital printing is performed at the producer as being the most beneficial. A number of critical productivity related factors for this scenario are identified in paper III, which gives guidelines on how to obtain high productivity when a digital printing task is integrated into a packaging line. It is finally shown that it is possible to obtain high delivery service and efficient logistics by using a hybrid printing solution. It is, however, of crucial importance that possible drawbacks be considered in order to accurately conclude whether a hybrid printing solution will be successful or not.

List of included papers

Paper I

Viström, M.: ”Customised information on packaging – business opportunities and consumer value”, *TAGA 2003 Proceedings*, Rochester, 2003.

Paper II

Viström, M.: ”Customised information on packaging – production flow and logistics for hybrid printing solutions”, *Advances in Printing Science and Technology*, vol. 30, Zagreb, 2003, pp. 181-194.

Paper III

Viström, M.: ”Ink-jet inline printing—identification and analysis of critical production related parameters”, to be published in *TAGA 2004 Proceedings*, Rochester, 2004.

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1 Introduction

1.1 Background

Print speed, print quality and reliability in digital printing equipment are improving continuously and many companies today express interest in digital printing solutions. Digital printing makes it possible to produce a specific printed matter on short notice since this printing process is not generally associated with a changeover time. It is possible to customize every printout because this technology uses no printing master. A more technical description of the different printing technologies can be found, among other places, in Kipphan, 2002.

The flexibility gained through a digital printing solution opens up new opportunities where information on the packaging can be customized for specific customer segments or individuals. There exist several notions in current literature that are closely related to customisation, such as personalization and individualization, although these have slightly different meanings. In this thesis, the notation "customisation of information" is exclusively used and the author has defined it as: ***adaptation of information for customer segments or individual customers, independent of whether or not the customisation task is customer driven.***

To profit from the use of digital printing, there has to be a market demand for customized information in one way or another or an opportunity to make production more effective. According to Kotler (1999), three situations can create market opportunities: 1) offering commodities that are in short supply; 2) offering existing products in a superior manner; and 3) offering a new product or service. It would be possible to offer products in a superior manner if information could be adapted to different customer segments.

"*As the core products become more and more alike, individualization/differentiation must largely be achieved through the packaging.*" (Olsmats, 2001, page 10).

I have used the statement above as a starting point for this thesis work and will look at the printing of the packaging as a way to ennoble the product. There exist several examples indicating a market demand for customized information. For example, a study of companies within the corrugated packaging market showed that 70% desired better ways to handle different languages, designs and stock; 83% desired a better correlation between marketing activities and the packaging (Fredriksen, 2002). Morgavi (2003) states that the driving force comes from customers that are increasingly demanding adapted products. There is a need for diversified designs on pharmaceutical packaging since different users handle the products in different environments (Rosenblad and Pousette, 1997).

Successful companies today operate in global markets to a higher extent than before. To satisfy the numerous valuations and preferences from customers, many of these companies are forced to incorporate a wider product assortment. However, it has become important to deliver customer-specific products in many lines of business, which means that a wide assortment of products is not always enough (Mattson, 2002). Mattson (2002), as well as Loutfy (2002), claim that the trend is to sell products prior to production, as opposed to the traditional business concept, where products are first produced and then marketed. This new business approach implies that the customers have already been identified at the production stage, which makes it possible to customize information on the packaging. Birkenshaw (2003) feels, however, that many product variants, different languages and legislation make it a difficult task to satisfy all packaging requirements.

A current trend is that there is little quality difference between similar products from different suppliers. This means that a strong brand name and packaging design are of paramount importance. The packaging design largely influences whether the customer will purchase a product (Olsmats, 2001). A good example is perfume, which would lose its sense of luxury and power of attraction if it were sold in neutral packaging. The packaging is often the only thing that differentiates one product from another (Packforsk, 1999). Since the demand for customized products and shorter lead times is expected to grow (Olsmats, 2002), tailored information on the packaging adapted towards customers or retailers could be an efficient way to make a product competitive and adapt it to market forces. Olsmats (2001) claims that packaging can function as a cost-effective marketing tool.

Once a company has decided that customisation of information on packaging can be useful in their business, they become faced with the question of how the customization can be achieved. It could be economically viable to use digital printing alone for smaller volumes, since, as opposed to conventional printing, there is no additional cost for a printing form. However, for larger volumes, the biggest perceived limitation of digital printing is that the cost is too high (Gillboa, 2002). The cost of ink for inkjet and electro-photography (two main digital printing technologies) accounts for a high percentage of the total cost of ownership (Kipphan, 2001). Birkenshaw (2003) states that the cost per printed unit for high volumes is still high compared with conventional printing, but through "on-demand" printing, cost savings in administration, distribution, waste, warehousing and production can be realized, which offsets the higher production costs. Hence, in addition to the potential marketing advantages, logistical gains are also possible through digital printing.

A combination of different printing technologies can be a way to minimize the increased cost per piece. Dante (2000) states that there are only certain areas that lend themselves to customisation since some of the information is the same for all pack-

aging. Therefore, a large part of the printing could be performed in advance. If conventional technology is used for pre-printing, large-scale advantages can be achieved when high volumes are produced. By adding digital print afterwards, we get a hybrid printing solution that has both the potential to achieve large-scale advantages and the possibility to customize information on each package. d'Heureuse and Kipphan (2001) say that conventional printing technology for pre-printing can also be used to obtain superior print quality

The notion hybrid printing is described by Kipphan (2001) as a printing system consisting of a combination of different printing technologies, combining, for example, 1) different conventional technologies, 2) non-impact printing (digital printing) technologies, or 3) conventional technology and digital printing technologies. The third approach is considered in this thesis.

A digital printing task can be performed at different places on the value chain. The production workflow of the whole system may be affected in different ways depending upon where the digital print is inserted. One option is to let the digital print addition directly follow the conventional printing process at the packaging producer. However, advantages such as flexibility and postponement of information binding can be achieved by adding the digital print further down the value chain at either the producer or the wholesaler/retailer level (see figure 1). According to Birkenshaw (2003), integration of digital printing in existing production workflows can realize savings and benefits.

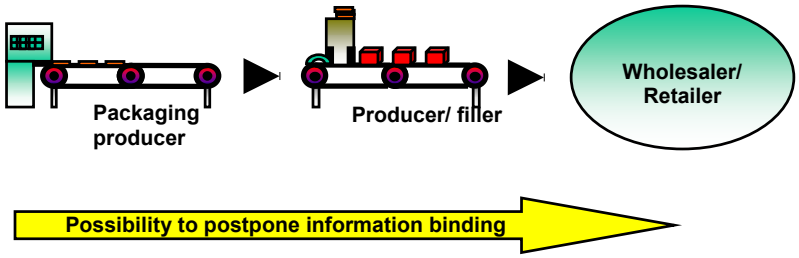

Figure 1. Different locations for integrating digital printing in a value chain

Inline printing of barcodes, best-before dates and batch numbers on packaging has been available for several years while more sophisticated customized printing of text information, logotypes and images in four colors is just now starting to catch producers' interests. According to Soroka (2002), color is the first thing an observer notices about a package and it is possible to evoke different emotional responses from an observer through color. Size, quality, value and flavor of a product can be perceived differently depending upon the color (Soroka, 2002).

Veresh (2003) emphasizes that for a digital printing solution integrated into an existing workflow to be successful, it must work satisfactorily in industrial environments and not create a bottleneck in critical situations. Hence, it is of crucial importance to uphold high productivity, which can be defined as "the ratio of output to input in a production process" (Evans, 1993). To perform the customisation task successfully, it is very important to consider the overall logistics and specific production workflow at the location where the customisation will take place. It is, however, necessary initially to have knowledge of the driving forces in the customisation of information on packaging. This knowledge is more or less a prerequisite to understand how the overall logistics and specific production workflow should be designed.

1.2 Thesis objectives

The purpose of this thesis is to identify and investigate *driving forces and limiting factors in the customisation of information on packaging and investigate how the customisation task should be performed to achieve high productivity and efficient logistics.*

1.3 Limitations

The driving forces to use customized information on packaging for the chosen lines of business, i.e., the pharmaceutical and food industry, are seen from a company's perspective. Only company respondents have been interviewed, which means that the end user or consumer has not been explicitly studied. All company studies with the exception of one were conducted in Sweden, giving this thesis a Swedish perspective. The focus is on consumer products, even though some aspects of business-to-business situations are also discussed. The section on logistics is focused mainly on the physical production workflow, even though aspects on information flow are also addressed. Information flow pertaining to the data flow needed to get proper information for variable data printing and customisation is not addressed. In addition, no environmental aspects are taken into consideration in this thesis.

2 Methodology

Methodological approach, research strategy and the research approach are discussed as important concepts to consider in the methodology literature. These concepts are described below and the research conducted within this thesis is put in its context.

2.1 Methodological approach

According to Abnor and Bjerke (1994), three methodological approaches exist within business economics: the analytical approach, the system approach and the actor's approach.

When using the analytical approach, reality is seen objectively and is a sum of the parts. This is contrary to the system approach, where the sum of all single parts in a system differs from the system seen as a whole. This approach is dependent on how the different parts affect each other (Abnor, Bjerke 1994). The whole system is usually divided into smaller subsystems in order to structure the reality. Spokesmen for the third and final approach, the actors approach, claim that knowledge is dependent on each individual, which means that the same facts and information become different knowledge for different individuals. It is important for an observer to understand how different individuals interpret the reality in order to understand the totality correctly.

The system approach is used in this thesis since several parts or processes have to interact with each other to provide customized information on packaging relevant to customers. Marketing aspects could definitely affect the production workflow and logistics in the customisation of information, as well as the other way around. Therefore, if would not have been convenient if one process were isolated from the other for the work conducted in this thesis.

2.2 Research strategy

It is possible to make a distinction between two different research strategies by 1) using theory before research is performed or 2) performing research in order to create theory. (Ghauri et. al., 1995). It is possible to use induction or deduction to draw research conclusions. When induction is used, empirical observations are made in order to make general conclusions. It is important, however, to know that it is not possible to guarantee that an inductive conclusion is 100% accurate. Theories or generally accepted principles are used to explain a specific phenomenon when deduction is applied. This procedure implies that it is possible to verify or reject what has already been accepted as a truth. It is also possible to exhibit consequences of already accepted principles (Depoy and Gitlin, 1999).

Induction was then used to draw conclusions from empirical investigations. Logical reasoning (deduction) was also used to draw conclusions when the findings were compared with established theories.

2.3 Research approach

According to Ghauri et. al. (1995), exploratory (unstructured), descriptive (structured) and causal research (structured) are the three main types of research approaches. Exploratory research is practicable when the research problem can be difficult to formulate and when new pieces of information may change the search for a solution. Descriptive research handles structured problems, which are easy to understand. An example is to investigate the size of a specific market. The researcher also investigates structured problems in causal research, but here the focus is to solve cause-and-effect problems. An exploratory research approach is used in this thesis since customization of information on packaging is a rather new area and exact research questions were rather difficult to formulate.

Case studies are used to study a case in-depth while cross-section studies are used to make a broad investigation at a certain time. A study can also be formed to investigate a development over time, i.e., a time series study (Lekvall and Wahlbin, 1993). Paper I is based on a cross-section study of a broader population while papers II and III are based on case studies.

Qualitative research and quantitative research are two different methods used for data collection. Quantitative research is used when the collected data can be expressed in numbers and can be analyzed by statistics. Qualitative research analyses and interprets information and is used when the data is not quantifiable. In qualitative research, the researcher is more interested to discover phenomenon and properties than to decide the extent of something that is already stated. Quantitative research is used when a pre-determined phenomenon is to be investigated (Lekvall and Wahlbin, 1993).

The three papers that together form this thesis are built mainly on qualitative studies. Since customisation of sophisticated information (more than simply batch numbers and best-before dates, etc.) on packaging is a rather new area, it was not obvious at the beginning of this research project which data was available and how to formulate accurate questions. Therefore, an unstructured qualitative method was chosen. It was convenient to conduct interviews in order to collect qualitative data with an unstructured method.

An interview can be structured, unstructured or something in between these two extremes. When a structured interview is conducted, the interviewer adheres to previously written documents with questions in a certain order. The respondent can often choose between different choices for his answer. Unstructured interviews are used mainly in qualitative research. The researcher initially introduces a subject field that will be dealt

with during the interview. Exploratory questions are thereafter put to the respondent. An exploratory question is a question that is neutral and doesn't lead the person to answer in a certain way. An example of an exploratory question is, "Can you tell me about your experience in this field?" (Depoy and Gitlin, 1999).

You should have a certain structure to your questions if you desire specific information and want to avoid getting too much irrelevant information. Most interviews are somewhere in between a completely structured and a completely unstructured interview. Unstructured interviews with a certain theme can provide much information.

The methodology in paper I is slightly different. It uses unstructured interviews based on a number of predefined themes (see paper I). Furthermore, in paper III, an interview guide (see appendix 1 and 2) was sent out prior to the interviews, which gave the respondents a chance to prepare themselves beforehand. The interviews during the visits were however unstructured, which implied that interesting information not covered by the interview guide also were found. The interview guide was however used as a checklist at the end of the interviews to assure that certain issues were addressed. This interview guide was developed together with a person working within the packaging industry. A quantitative data collection was made in paper II to obtain cost figures for potential savings using a hybrid printing solution instead of conventional printing. Qualitative data was collected at the same time.

The papers are mostly based on primary sources (respondents at selected companies) and my own observations at the companies. In addition, secondary sources (books, articles, Internet) are used to obtain information about related research and to collect relevant theories for use in the analysis. Details on how companies and respondents were selected are found in each specific paper.

3 Theoretical framework

3.1 The packaging

Humans have used packaging from time immemorial to store and transport food and other possessions. The earthenware vessel believed to have been used 8000 years ago is one example (Andersson et. al, 1997). A wide variety of materials are used currently when packaging is produced and Soroka (2002) states that today's packaging can have both technical and marketing related functions. According to Soroka (2002), packaging is best described as "*... a coordinated system of preparing goods for transport, distribution, storage, retailing and use.*" (Soroka 2002, page 3). He claims that packaging can be seen as a service function that needs a product in order to exist (Soroka, 2002). In this thesis, this approach is used as a definition of the packaging. Lumsden (1998) describes the role of the packaging in a logistics system and states that its function is to:

- protect the product
- protect the environment
- support return shipments
- make the product easy to handle
- **provide information about the product and how to use it**
- **provide a commercial function**

The two last points are considered in this thesis since printing is the issue. Packaging is usually divided into three levels when described in literature: consumer packaging is defined as primary packaging; a multi-pack of primary packaging is defined as secondary packaging; and the third level is transport packaging, which is called tertiary packaging (Dominic et. al, 2000). The focus in this thesis is on primary packaging.

Dominic et al (2000) emphasize that no component other than packaging has so many and such contradictory demands. These demands can be divided in three categories: flow (logistics), market and environment (see figure 2). Packaging can meet flow demands with characteristics that facilitate the handling of the products and render the production, distribution and interaction between packaging and customers more effective. Market demands can be met by providing an added value onto the packaging, for example an appealing design, one that makes it more attractive. Environmental demands consider minimizing the load on the environment (Dominic et al, 2000). The scope in this thesis is on the flow and market demands; environmental aspects are not considered.

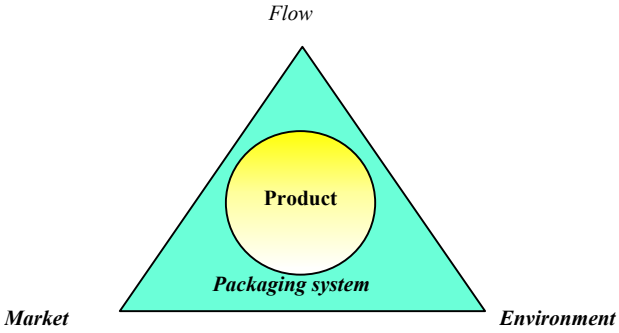

Figure 2. Packaging demands (Based on Dominic et. al., 2000)

3.2 Marketing aspects

Since a specific product cannot appeal to every buyer, it is advantageous to identify market segments and develop products and marketing mixes to meet different customer demands (Kotler et. al., 2002). There are two extreme methods of marketing: mass marketing and micro marketing (complete segmentation). Between these two extremes are segment marketing and niche marketing. To better reach the customers, companies can divide a large heterogeneous market (where mass marketing can be applied) into smaller segments and thereby offer products adapted for each segment. Segments normally consist of large identifiable groups based on geographic or demographic variables. A subgroup within a segment is called a niche and the idea behind niche marketing is to satisfy more precisely the customers' needs. The most extreme method of marketing is micro marketing, where products and marketing are tailored to fit local markets or specific individuals. (Kotler et. al., 2002). Marketing towards individual customers can also be referred to as one-to-one marketing.

According to Kotler (2000), one-to-one marketing can lead to the capture of market shares, customer retention and improvement in customer satisfaction together with an increased return on investment. One-to-one marketing builds up relationships with customers through a series of collaborative interactions. With one-to-one marketing, the focus is on each individual customer and companies can differentiate not only the products, but the customers as well (Peppers and Rogers, 1993). The difference between one-to-one marketing and traditional marketing is that the traditional marketer tries to find as many customers as possible for its products while a one-to-one marketer tries to find more services and products for its established customers (Peppers and Rogers, 2002).

When there are dealers, distributors, retailers or other channel members between the selling company and the end-user, one-to-one marketing can be much more difficult to introduce (Peppers and Rogers, 2002). Peppers and Rogers (2002) claim, however, that

if you have channel partners that stand for more than just inventory and delivery of products to end-users, it is probably a good idea to use the principles of one-to-one marketing to strengthen the relationships with these partners.

An important remark is that one-to-one marketing is often discussed as a business concept where many information channels are used together to interact with the customer. In this thesis, the considered information channel is the packaging itself, which means that the concept of one-to-one marketing is used in a slightly different way.

Kotler (2002) discusses push versus pull strategies. A push strategy implies that the company focuses its marketing activities towards actors, e.g. retailers, in the value chain to have them promote the products to end customers. When using a pull strategy, the marketing activities are directed towards the consumers to attract purchases. If these marketing activities are successful, the consumers will demand products from the actors in the value chain, who will in turn demand these products from the producers.

3.3 Marketing channels

According to marketing channels literature, it is possible to define a number of gaps that illuminate the different requirements and aims between the producer and the customer (Christopher, 1994, page 131). (Words within pharentheses means that a free translation used in paper II differs from the names (within brackets) used by Christopher (1994)).

Time gap – Producers produce continuously to achieve large-scale advantages, but customers buy products at discrete intervals.

Geographical gap (space gap) – Customers are scattered over a large geographical area, while producers are located at a small number of places.

Quantity gap – Consumers often like to buy small quantities, while companies produce large volumes.

Variant gap (**variety gap**) – Customers have different needs and demand many variants, while producers offer a limited numbers of variants of a product.

Communication and information gap – Producers do not always know who and where the potential buyer is to be found. At the same time, the desired products are not always accessible for customers.
(Christopher, 1994)

Abrahamsson (1992) claims that the marketing channels literature is characterized by a desire to achieve a geographical nearness to customers. There is a direct connection between distribution and marketing and the difference between having many small cust-

omers versus a few big customers is reflected in the number of intermediaries. Many small customers would lead to more intermediaries (Abrahamsson, 1992). Intermediaries in the marketing channel are expected to create benefits and bridge between gaps in a more effective way than the selling company (Christopher, 1994). Besides supplying goods in an efficient way, intermediaries also stimulate demand using promotional activities (Stern and El-Ansary, 1992). Stern and El-Ansary (1992) further emphasize that the efficiency in marketing channels is promoted by the opportunity to postpone specifications of the product.

"Postponement promotes efficiency by moving differentiation nearer to the time of purchase when demand is more certain, thus reducing risk and uncertainty costs."
(Stern and El-Ansary, 1992, page 22)

3.4 Logistics

There exist several definitions of logistics. For example, the Council of Logistics Management (the largest organization for logistics in the USA) defines logistics as: "*the process of planning, implementing, and controlling the efficient, effective flow and storage of raw materials, in-process inventory, finished goods, services, and related information from point of origin to point of consumption(including inbound, outbound, internal, and external movements) for the purpose of conforming to customer requirements.*" (Person and Virum, 1996, page 13). According to Johnsson (1998), many logistics persons in the industrial sector used this definition. I agree with this definition, but I have chosen to explain logistics using a definition by Lumsden (1998), saying that logistics is about getting the right product with the right quality to the correct place at the precise time at a minimum cost.

Through logistics most companies want to increase their profitability or at least retain it. There are three different ways to increase profit and improve the profitability, although the best method is to use all three (Lumsden, 1998).

- Reduce costs
- Increase receipts
- Decrease the capital tied to different types of stock.

Business is created through marketing while logistics is needed to complete the sales process. The efficiency of logistics can be described in terms of delivery service, costs and binding of capital (see figure 3). These terms are dependent on each other whereby all of them have to be considered to know the complete effects when one factor is changed. An improvement of the delivery service may for example give a higher binding of capital.

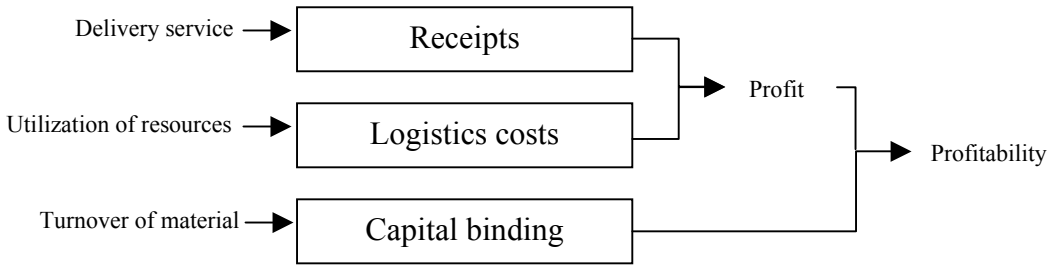

Figure 3. Connection between logistics and return on asset (Lumsden , 1998, page 225)

According to Lumsden (1998), there is a strong connection between marketing and logistics, foremost through the conception of service. Customer service includes everything that concerns the relationship to the customer. According to Stock and Lambert (2001), customer service may be the best method to gain sustainable competitive advantages for a company. Product accessibility and lead-time can, for example, be utilized to differentiate a product. It is possible to adjust the market price as long as the customer is willing to pay for better service. A lot of companies are, however, implementing the same customer service strategies as their major competitors. Stock and Lambert (2001) emphasize that the gains from providing better customer service have to be counted in relation to higher logistics cost. It is also important to be aware of that the function of the production constitutes a very important condition as to how the distribution systems can be developed (Person and Virum, 1998).

3.4.1 The supply chain

There are many definitions of supply chain. Dominic, et al (2000) present one packaging-related approach shown in the flowchart in figure 4, where an outline of the different actors in a packaging system is presented. Factors related to environmental aspects, such as landfill and incineration for reuse, are excluded from the original flowchart (Dominic et al, 2000) since these are outside of the scope for this thesis.

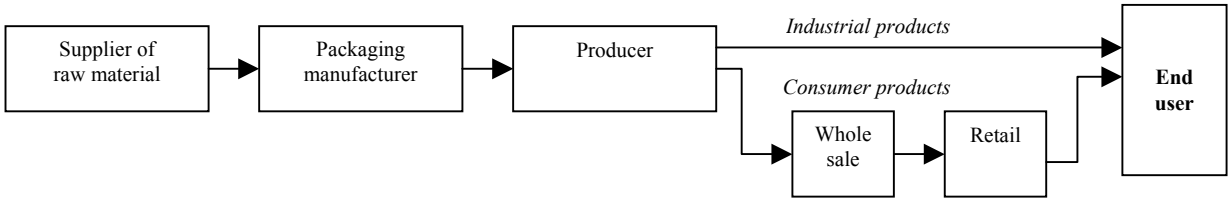

Figure 4. Packaging in the supply chain (Based on Dominic et. al, 2000)

3.4.2 The order penetration point

There exist different principles to control a company's physical flow of products. The major difference between these principles is whether the production is initiated by prognosis or customer orders. If customer expectations of fast delivery exceed the producer's ability, the products have to be delivered from a stock of finished goods, which can possibly be replenished according to a prognosis. On the other hand, if the customer is prepared to wait on the manufacture of its ordered goods, it is possible to start production once an order is received, which provides an opportunity for customisation. There exist different levels of management in customer orders. For some products, the customer order might initiate construction and materials supply, while the order initiates only the final assembly for others. The point between managing by prognosis and customer order is called the order penetration point (see figure 5) (Lumsden, 1998).

Olhager (2003) states that the different ways to manufacture, such as made-to-stock (MTS), assessable-to-order (ATO), made-to-order (MTO) and engineer-to-order (ETO), all relate to different positions of the order penetration point. According to Olhager (2003), many factors influence the positioning of the order penetration point. Lead-time requirements and flexibility in the production process are two examples of influencing factors. According to Olhager (2003), there are two major driving forces to shift the order penetration point forward in the value chain: (1) reduction of delivery lead-time; and (2) increment of the manufacturing efficiency by not having to react to exact customer order items and quantities. A forward shift implies, however, a need for more pre-fabrication and thereby less opportunity for customisation. There is also a risk for obsolescence since the production relies more on forecasts (Olhager, 2003).

The possibility to have a higher degree of customisation and a reduction in the amount of work-in-process inventory are the two main driving forces to shift the order penetration point backwards in the value chain. The major requirement for backward shifting is a reduction of the lead-time of downstream activities needed to maintain the delivery lead-time (Olhager, 2003).

Aronsson (2000) discusses the need for keeping stock and lead-time reduction vs. capacity flexibility. He claims that the time available for order fulfillment is always shorter than the logistics lead-time for the whole supply chain, which implies that the supply chain needs to be split into a number of order-and-delivery cycles separated through stock-keeping. The location and size of the stock can be influenced, but there will always be a need for it. He further states that a short lead-time is often emphasized as very important, but that it is to some extent more important to have a stable delivery time. It can be expensive to increase capacity flexibility, but Aronsson (2000) states that it has been considered more expensive to have unstable delivery lead-times. He concludes that lead-time reductions in production can either be used to shorten delivery times or to increase flexibility.

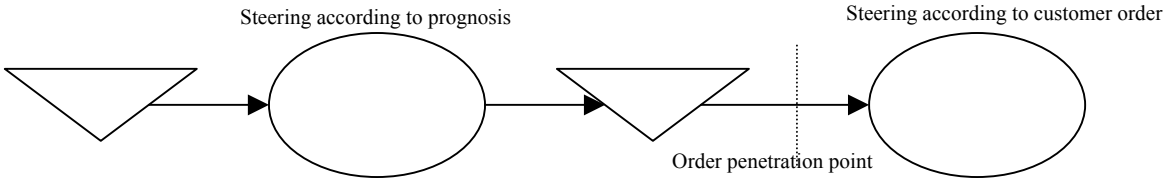

Figure 5 Steering according to prognosis and customer order (Lumsden, 1998, page 247)

3.4.3 Efficiency

Efficiency in logistics can be defined as the level of purpose accomplishment and can be described as the benefits achieved through performed efforts. As explained in *3.4* the logistical efficiency can be described in terms of service, costs and capital binding. Efficiency can also be divided into internal and external efficiency. Internal efficiency refers to how well the company manages their internal processes, such as having a well-working system for administration and materials handling. External efficiency refers to how the companies interface with external actors and can be improved through a well-designed delivery service. Hence, efficiency is about making the right things while productivity describes how to do things right. The relationship between productivity and efficiency is described in figure 6 (Lumsden, 1998).

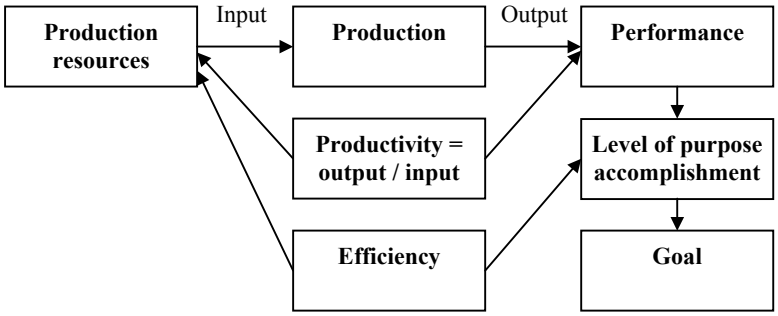

Figure 6. Relationship between productivity and efficiency (Lumsden, 1998, page 618)

3.4.4 Delivery service

Delivery service is defined as a subset of customer service and includes the parts of customer service that are related to the physical workflow. According to the discussions above, it is important to consider delivery service to create a high external efficiency. Delivery service is usually divided into the following factors: delivery lead-time, delivery precision, delivery safety, delivery rate, flexibility and information (Lumsden 1998). It should, however, be emphasized that other factors might be included in delivery service. A more detailed description based on Lumsden (1998) is found below.

Delivery lead time
Delivery lead-time is the time that passes between receipt of the order and delivery. During the lead time activities such as receipt of orders, handling of orders, planning, construction (if necessary), manufacturing and distribution, are performed.

Delivery precision
Delivery precision is the ability to deliver at the exact time promised to the customer. The importance of delivery precision increased when concepts like ”just-in-time” were introduced. Good delivery precision can possibly be more important than a short delivery time.

Delivery safety
Delivery safety is defined as the ability to deliver the right product in correct quantities and quality. With today’s trend of “just-in-time” deliveries and minimal stock levels, there is no room for faulty deliveries.

Delivery rate
Delivery rate describes the ability to deliver directly from stock and can be expressed as the probability to deliver a finished product from stock. Safety stock and delivery rate are closely connected to each other.

Flexibility
The capability to adapt deliveries according to the desire of customers is important. Customers might demand specific order sizes, packing, delivery address, documentation, etc. Flexibility can also point to finding new solutions to make deliveries problem-free. Good flexibility can be a major competitive factor.

Information
Of great importance is to have a well working system for exchange of information between the producer and the customer. When deeper co-operations are established between different companies there will be higher demands to integrate information systems. Since information flow is not the main scope of this thesis no further discussion or analysis will be made.

4 Related research

Research that I have found interesting during literature reviews is described in this chapter. Research related to driving forces is first discussed and research related to logistics and production workflow thereafter. The different authors are otherwise not quoted in any particular order.

Driving forces

Olsmats (2002) views packaging as a strategic tool for business development and states that even though companies use packaging to gain competitive advantages, they are far from utilizing it fully in this respect. Consumer demands on packaging is one of the most critical factors of future packaging demands. The mass market seems to lose ground and is replaced by market segments with particular requirements. Therefore, there is a need for more customized marketing to attract specific segments of customers, especially since consumers tend to be more and more heterogeneous. The future of food packaging may be to combine centralized large-scale production of semi-finished goods with small-scale customisation at local facilities. This way to combine different concepts implies a need for new packaging solutions. The added value from the packaging can often be the deciding factor as to whether a company is awarded an order or not (Olsmats, 2002).

Olsmats (2002) further discusses results from Teknisk Framsyn 2000 (a technology foresight project in Sweden) where is it stated that individualization and borderlessness are seen as two major driving forces in development. A demand for more individualized products and non-existent borders in trade, culture and capital, and the relation between work and leisure time set new demands on packaging. For example, travel increases every year and destinations become more exotic. People look for exotic products on their local store shelves more than ever before (Olsmats, 2002). According to Teknisk Framsyn (2003), companies will use customized products as a means to compete, even though in some circumstances the customers don't have the competence or desire to pick through all the details. Manufacturing of individualized products will be made through the mass-production of standardized products and modules, which will be combined to form unique products adapted to specific customers. This final customisation will often be carried out close to the customer (Teknisk Framsyn, 2003).

Olsmats (2002) also claims that older people seem to be ready to pay for adequate information and packaging size. He shows through a marketing investigation that product information and packaging size were ranked to have almost the same importance as a low price. The older population is growing, which implies an increasing need for nursing and health care. This rising need, together with a decline in household sizes, set high demands on product information. He emphasizes the importance of information that is easy to read and easy to find. Distance health care with customized instructions is predicted to be a prerequisite to handle increasing cost of nursing care (Olsmats, 2001).

Podi is a non-profit organization promoting the potential of digital printing and developing standards for variable data printing. It has gathered a rather large number of success stories from companies using digital printing solutions in different ways. Podi (2003) also studies how to make segmentation effective and investigates how variable data can improve business. Most of their case studies, however, are focused on document printing and not on the packaging area.

Podi (2003) claims there are two economical forces driving the success of digital printing: increased effectiveness (documents working as effective business tools) and increased efficiency (workflow). Podi (2003) also claims that 30% of the companies in their case studies use both. A number of factors have been identified from the case studies that could be used to improve a document's ability to affect a consumer: familiar and interesting content, clear layout, customized offerings to a specific individual and delivery of something specific according to a specific order. Podi (2003) says their case studies show that these factors can be used to improve response rates, response time, average order value and speed up bill payment. Over-capacity and near zero-margins within the printing industry imply that printers need to offer viable value propositions in their printing to create profit (Podi, 2003). One of the case study companies, Package GENIE, uses digital printing to produce tailor-made packaging. Their customers can order specific sizes of (corrugated) boxes with customized designs. Instead of needing one to several weeks lead-time, as might be the case in conventional printing, they can deliver the packaging material in four days (Podi, 2001). The printing process is solely digital and is based on inkjet technology (Forcinio, 2002).

Dielmans (2001) emphasizes the importance of having prototype packaging. He claims that there is permanent drive to introduce new or modified products to the market in order to keep the economy going. There is also a rising need to create for more sophisticated packaging, which means that several parties are involved, i.e., designers, packaging suppliers and the packaging user (filler). When new packaging is to be developed, the filler is the one that will take the risk if the packaging sells badly on the market. Dielemans (2001) claims that a poor design is equal to a poor return on investment. He concludes that the earlier a printed sample is made, the greater the chance to control the project.

Löfgren (2004) shows that it is possible to see the packaging as a carrier of prerequisites for service. He also discusses "the first moment of truth", which is catching the customer's attention with the packaging, and "the second moment of truth", which reveals whether the information, functions, etc., forming the prerequisites for service are satisfactorily. Since there are no employees present at the consumption process, companies need to provide user-friendly prerequisites for service. Löfgren (2004) states that his investigation shows that one main goal from respondents representing companies selling consumer goods was to create repurchase, which is achieved through winning

the second moment of truth. Customers here will prioritize certainty of performance and ease-of-use. He concludes, however, that a customer can evaluate a product both at the time it is purchased and when it is consumed and experienced.

Logistics / production workflow
Johnsson (1998) claims that packaging and logistics are usually considered as two independent disciplines. He divides the conception of added value from packaging into two components: product value and service value. A higher product value means that it is possible to increase the price of the product. Service value is about making the distribution more cost effective, which in his work is referred to as packaging logistics. One conclusion drawn from case studies and a survey is that it can be a complex task to integrate packaging and logistics. The packaging discipline is fragmented and logistics people tend not to focus on packaging. Johnsson (1998) concludes that most companies view packaging as a cost driver and are not considering the potential benefit regarding cost savings in the logistics chain. He further concludes that packages can be used to improve lead-time, ergonomics, environmental aspects, etc. Johnsson (1998) states that there has been a lack of research concerning integration of logistics and packaging in order to make handling and distribution more cost effective.

Dominic (2004) says there is a gap in synchronizing the packaging supply chain with the consumers demand chain. He further states that very little research has been conducted on the packaging supplier from a logistics viewpoint. Results from his studies show that there have been problems conveying information on consumers' demands to the packaging suppliers. He also implies that the product filler is not involved in the marketplace activities. Integrating the packaging supplier into the supply demand chain could lead to higher consumer satisfaction and reduced logistical costs. Customers' demands and expectations of the products and services vary. Dominic claims that previous studies show that the customers' expectations on packaging suppliers' knowledge were higher than suppliers could live up to. Therefore, the packaging industry is challenged to differentiate their services to satisfy their customers. Dominic (2002) claims that there is a need for an independent actor who can keep the value chain together.

Dante and Karles (2001) have investigated how to make an inline digital printing system for industrial packaging applications. They feel that advancements in inkjet technology imply that the technology can be used for more sophisticated packaging printing other than just bar coding, etc. They see a large potential in the technology for promotion and marketing through customisation of information on packaging. Since some of the information is fixed among all packages, a hybrid printing solution where variable information is added through digital print is an interesting concept. They also see potential use for the flexibility gained in the production, since production schedules change frequently and often at the last minute. Large buffer stocks of different preprinted packaging material needs to be stored when conventional methods are used,

which implies higher inventory costs, administration costs and significant waste. Digital printing could be used to solve this problem, but Dante and Karles (2001) stress that significant investments and development are necessary before the technology is ready to be used.

Dante and Karles (2001) also discuss where in the packaging process the digital print should be added. They feel that the most flexible way is to have the digital printing task incorporated into the final packaging step, i.e., integrated into the packaging machine. This would, however, increase the risk for production stops since printer equipment failure would stop the entire packaging line. Their alternatives for placing digital printing at other positions are further discussed and compared with scenarios defined by the author in paper II.

Dante and Karles define elements required for success:

- Because the printer unit sets additional demands on the production process and operators, the gains and savings must more than offset the additional costs.

- Print quality should be comparable to current standards but this demand can be relaxed when only small variable parts are printed.

- Operators should not be burdened with additional tasks that demand complex training.

- The equipment should be reliable and not affect the throughput of the packaging line.

- It is also important that the equipment can easily be replaced and upgraded.

Many parameters have to be considered when a hybrid printing unit is used. Some issues are drying times, water and abrasion resistance, reliability and speed. Dante and Karles (2001) claim that speed and resolution requirements are highly dependent on the type of product and packaging.

Mitchell (2001) states that logistics and stockholding costs of coping with pre-printed packaging can be very high and he sees a growing demand for more flexible printing. He has investigated in-line carton printing of secondary packaging (one-color). He claims that the biggest problem with secondary packaging is the variable quality of the material, which is often made from recycled board. He defines different points in the value chain where the printing can take place, meaning that online printing would give the greatest benefits. It can, however, be difficult to print on secondary packaging inline since printing has to be done on erected and filled cartons that move in a more or less uncontrolled way with vibrations and dust issues. He further describes an installation of offline printing of flat blanks at the filler and thinks this way appears to be the most

ideal positioning. It is less flexible than an inline solution but it gives the possibility to produce short series without disturbing the packaging line. An alternative to printing directly onto the packaging is to print labels and attach them onto the packaging. According to Mitchell (2001), the main disadvantage of labels is the cost.

5 Summary of results

5.1 Paper I: Customised information on packaging - Business opportunities and consumer value

The aim of the work presented in this paper is to gain knowledge about the driving forces in the customisation of information on packaging. Limiting factors are also identified. Two lines of business working under fundamentally different conditions are studied to give a wide perspective on the issue. The food industry competes in stores on a mass market while the pharmaceutical industry represents another category where formal demands, security and legal issues are important. A cross-section study of 10 companies in the food and 9 companies in the pharmaceutical industry was performed during 2002 and 2003.

It is shown in paper I that customized information on packaging has the potential to give products higher market value and increased customer satisfaction. The driving forces for applying customisation, concluded in the paper, are an increasing competition between companies, higher demands from retailers and the possibility to give consumers added value.

In addition to the three factors mentioned above, figure 7 shows conclusions about how consumer- and market value can be achieved by adding customized information on packaging. In the findings there are more aspects on creating consumer value within the pharmaceutical industry than within the food industry. In addition to the results presented in figure 7, findings in paper 1 also indicate a potential need for customisation of information according to age and the level of the user's experience (first time user, advanced user).

Customisation for individuals
Pharmaceutical*:* instructions aimed at patients and assistants → **consumer & market value**

Customisation for groups of individual with the same characteristics:
Food*:* differentiation of information / pictures on packaging → **market value**
Pharmaceutical*:* differentiation according to the patient's sensitivity to reveal his/her need for pharmaceuticals → **consumer value, market value**

Customisation for a geographical area:
Food: adaptations according to languages, tailoring according to the ability to read and according to the origin of local products → **consumer value, market value**
Saleable product names → **market value**
Conditions in the store → **market value**
Pharmaceutical*:* language → **consumer value, market value**
Name of retailer → **market value**

Figure 7. Consumer and market value

What seemed like a driving force in the first place might not be a motivational force in reality if other preventive factors exist. Hence, it is important to consider eventual limitations as well. Results in this paper indicate that the logistics become more complex when the number of versions increases. As products are passing through a central warehouse, before they are shipped to retailers, it would be more difficult to reach the right customer. Packaging for food is especially very price sensitive, which means that the packaging cost is a critical factor. The analysis also shows that one-to-one marketing using the packaging itself as an information channel is still a challenge for stores. Furthermore, gaining approval for pharmaceuticals from authorities is a long process where every single change must be approved. Therefore the concept of faster updates is difficult to accomplish. The producer's responsibility for his product also limits the possibilities to customize information later in the value chain, i.e., at the pharmacies. Moreover, personal integrity is an issue that needs to be carefully considered, especially within the pharmaceutical industry. More packaging designs also imply more demands for designers and copywriters. According to the results, these activities are considered expensive and will therefore limit the potential benefits of having customized information on packaging.

5.2 Paper II: Customised information on packaging – production flow and logistics for hybrid printing solutions

The idea of a hybrid printing solution is investigated and discussed in this paper. It deals primarily with two particular cost carrying parameters at a conventional flexography printer: changeover costs and print form costs. These costs limit new production strategies where more packaging versions in smaller quantities are used. It is discussed in this paper how a hybrid printing solution could overcome these limitations.

Possible scenarios about where in a value chain digital print can be performed are described in this presented work. The different scenarios are defined as having a digital print performed 1) directly after packaging is produced at the packaging producer, 2) at the filler (manufacturer of products) or 3) at the wholesale dealer or retailer. Where these scenarios are described in the published paper, the words *wholesale dealer* and *retailer* are unfortunately inconsequently used. *Wholesale dealer/retailer* should have been used consequently, defining a scenario where the digital printing task is performed somewhere after the packaging has been filled at the producer. Many parameters affect costs and the optimal location of the digital print. There are, however, factors pointing to the second scenario as the most beneficial in many situations.

The study is based on interviews and observations of the production of wrapping paper for reams at a flexography printer. Cost figures for the production were collected. The printer's largest customer, a producer of reams, was also studied in order to map out their demands and the potential gains of having customized information added onto the packaging.

The study shows that a hybrid printing solution combining flexography and digital printing can imply a reduction of changeover- and cliché costs when shorter series are produced. It is also shown that a hybrid printing solution could result in stock reduction, shortening of lead-times and a higher flexibility in production.

However, the logistical savings and the added value from providing customized information on packaging have to be evaluated in relation to the additional customisation costs so as to ascertain whether or not a hybrid printing solution to provide customized information on packaging is economically viable (see figure 8).

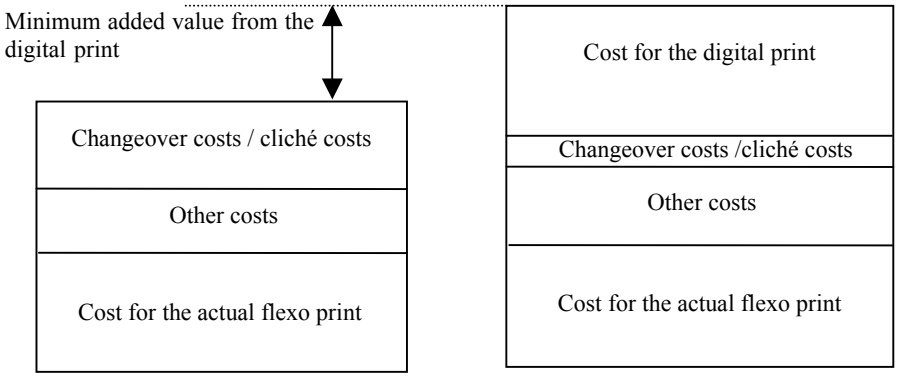

Figure 8. A minimum value from the digital print might be needed to make hybrid printing economically viable.

It is also discussed in this paper how a hybrid printing solution can reduce the size of the existing gaps between producers and consumers by customizing information on the packaging (see illustration in figure 9). A hybrid printing solution can make it possible to reduce the variant gap, quantity gap, geographical gap and time gap.

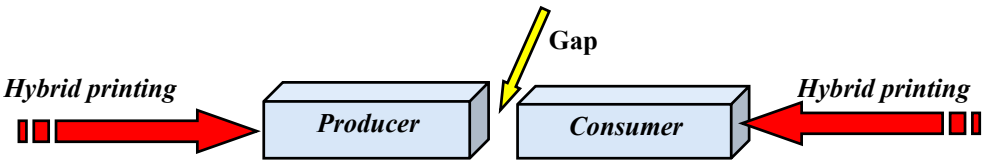

Figure 9 Reduction of gaps through hybrid printing

5.3 Paper III: Inkjet inline printing – Identification and analysis of critical production related parameters

It was stated in paper II that many parameters have to be considered to evaluate the benefits and drawbacks for hybrid printing solutions and to find the optimal location for the customisation task (digital printing). In paper III, this work is continued for scenario II, adding the digital printing task at the producer.

The aim of the work presented in this paper is to investigate how a digital printing task should be integrated into existing packaging lines in order get high productivity. The study is focused on inkjet technology, which is considered a viable digital printing technology for customisation of information inline. The purpose is to identify critical productivity related factors in high speed inkjet printing and investigate whether these factors work well in conjunction with current production lines or not. The paper focuses on inline printing, which means that offline printing solutions are left for future studies.

Two users of high-speed color inkjet equipment are used for case studies: a label printing company and a producer of industrial products sold primarily to business customers. In parallel, three typical packaging lines are studied: the largest pharmaceutical company in Sweden, a producer of pasta and cereals and a producer of dairy products.

A number of productivity-related factors are identified through the analysis of the results. The following factors should be considered to achieve high productivity when a high-speed inkjet printer system is to be integrated into a packaging line.

Productivity related factors in high-speed inkjet printing:

- Print speed
- Reliability
- Print quality demands
- Operator qualifications
- Preventive maintenance
- Right climate
- Supervision

Critical factors in packaging lines

- Start-up time
- Reliability
- Sufficient over-capacity
- Operator qualifications
- System for removal of misprints
- Number of different substrates

5.4 Reliability and validity in the papers

Since this thesis is based on qualitative case studies, it is not possible to guarantee that a generalization of the results would correspond to the reality. The number of studied companies had to be limited in order to keep the research work within the time frames. By carefully choosing representative case study companies and respondents, the results should, however, give a good indication of the reality.

For practical reasons (economical and geographical), companies in Sweden were mainly chosen for the studies. One case study, however, was conducted abroad but it focused for the most part on a printer system and a packaging line to find out the critical factors for the technology, a study relatively independent on the geographical location.

There is always a risk that the investigated population does not match the goal population or that the selected respondents are not representative. Since a considerable amount of time is spent to find the most representative persons within the companies, I have tried to minimize this risk. It is also possible to get measurement errors if the respondents are not able to answer a question correctly or give an accurate description. There is also a risk that the interviewer misinterprets the respondent. I have tried to minimize these risks by contacting the respondents whenever something needed to be clarified during the structuring of collected data. These types of errors could lead to low validity and reliability.

According to Lekvall and Wahlbin (1993), validity explains whether the method used is really measuring the right thing, while reliability describes how well the measured data will correspond to repeated measurement. According to the statement above, steps have been taken to minimize the risk of low reliability. Validity can be divided into internal and external validity. Internal validity describes how well the results within the study correspond to the reality, while external validity describes if the results can be generalized to other populations, periods, etc. (Ghauri et. al, 1995).

The cross section study in paper I covers a rather broad population (having interviews at several companies), which means that it should be easier to assure the results are valid at these lines of business in Sweden. However, since an unstructured research approach was used, respondents from different companies sometimes described things from different angles and did not always address the same issues. Hence, by using this unstructured research approach, it was sometimes difficult to find statements that were supported by several respondents. To assure a good internal validity, the advantage of conducting several interviews was accordingly reduced to some extent. When regarding the external validity, it should be possible to generalize the results in paper I as valid for the same lines of business in other countries, where legislation and business situations are similar to Swedish conditions. One important remark is that many companies had limited experience using customized information on packaging, which means that some

of the results in paper I regarding possible applications are to some extent based on what the respondents believed would be interesting applications.

How well the cost figures collected in paper II will correspond to the cost figures at other flexography printers could be discussed. It was assumed that the press could have been running a job from a full order stock during the changeover time and the calculations are based on an average number of changeovers during the course of a year and price levels at this specific company. For companies without a full order stock, changeover time would not be as critical. Hence, it could be difficult to generalize the cost figures as valid for other flexography printers unless a number of conditions are fulfilled. It is also possible that changeover times will change due to technology developments, which then would affect the validity across time. The purpose, however, was not to get a precise monetary answer but rather to give an indication of costs and to investigate general benefits by having a hybrid printing solution.

While several different packaging lines are studied in paper III, the results should be applicable for almost any packaging line for primary packaging, i.e., external validity should be high. However, since technology development is progressing quickly, new technology might eliminate some of the factors considered as critical in paper III. Hence, the reader should be aware of this influence of time since it means that the validity across time could be affected.

Paper I focuses on the food and pharmaceutical industry while paper II focuses on the production of packaging for reams in the paper industry. In paper II, the paper company's need and desire for a shorter product series gave input to the calculations of changeover time and cliché costs and formed a base to analyze the potential gains of having a hybrid printing solution. Other data would likely have been found for a company in the food or pharmaceutical industry, but these companies were convenient to study and easy to access for a general packaging supplier/producer scenario and to investigate potential gains from a hybrid printing solution. Furthermore, the paper producer had already started to minimize the number of standard versions of packaging and instead customized them with labels, which made this company interesting to study. In paper III, the focus is back on the pharmaceutical and food industry even though the leading users of inkjet technology are found among other lines of business.

6 Analysis and discussion

6.1 Driving forces

By adding customized information to the packaging, it is possible to address specific information towards specific segments of customers or, in the extreme, towards specific individuals. Hence, marketing efforts can be directly addressed towards consumers, which means that packaging can be used as an information channel applying a pull strategy.

It is stated in paper I that the driving forces can be summarized as the *potential possibilities for an increase in market value and consumer value*. It is also concluded that there is an increasing competition among companies and increasing demands from retailers, which stresses the importance to create market value and consumer value. Löfgren (2004) talks about winning the first and second moment of truth when the customer connects with the packaging, which would correspond to the market and consumer values discussed in paper I.

Löfgren (2004) points out that one main goal for companies selling consumer goods is to create repurchase, which is achieved by winning the second moment of truth or creating consumer value. He claims that customers will prioritize certainty of performance and ease-of-use. In my findings in paper I, this would correspond to customized instructions on pharmaceuticals, customized information according to age and level of the users experience and language. Personal integrity would also be an important consideration to win the second moment of truth. An important remark, however, is that my conclusions are based on answers from respondents at the companies and not from the consumers themselves. Olsmats (2002) states that consumer demands is one of the most critical factors regarding future packaging demands. Furthermore, the foreseen increasing demand for health care from a distance emphasizes the need for customized instructions (Olsmats, 2001).

Löfgren (2004) claims that a customer can evaluate a product both at the time it is purchased and when it is consumed and experienced. In my findings, the driving forces behind customized information have a slightly bigger focus on creating market value rather than consumer value. This might be natural since printed information can be used to attract customers while other functions, such as an opening device, might be more dominant at the second moment of truth when consumer value is created. The market aspect is also emphasized by Olsmats (2002), who claims that there is a need for more customized marketing to attract specific segments of customers who tend to be more heterogeneous.

The findings in paper I, showing how consumer and market value can be achieved, are strengthening and complementing the findings of Podi (2003), who has identified a number of factors that can be used in a document to affect the consumer: *familiar and interesting content, clear layout, offers customized to a specific individual and delivery of something specific according to a specific order.* Podi (2003) claims that their case studies show that these factors can be used to improve response rates, response time, average order value and make bill payment faster. It is not possible to directly compare documents with packaging, but I believe that Podi's (2003) findings would give an indication of improvements that are possible to achieve when packaging is adapted according to these factors. My findings in paper III show that a digital printing solution in a packaging line can be used to improve customer satisfaction. One of the case study companies had started to campaign and create special versions for different customer segments, for example, providing different co-brands on the packaging. This company had accordingly started a move from mass marketing to segment marketing and had confirmed improved customer satisfaction. Hence, this case shows that digital printing can be used to make a successful move towards a segmentation strategy which is in line with Kotler (2000) who claims that such a move creates opportunities to capture market shares and increase customer retention and customer satisfaction. An important remark is that this company were selling products to business customers.

It is obvious that one of the main driving forces to use customized information on packaging is to better reach the customers, which can be described through analyzing the gaps between producers and consumers, defined in the marketing channels literature. It is shown in paper II that it would be possible to reduce the size of the variant, quantity, geographical and time gap by using a hybrid printing solution, having the perspective that printed information on the packaging is part of the product offer. Respondents in paper I claim that distribution and production factors have to be considered before a new product is designed and introduced on the market and claim that conflicts between the marketing and production departments can easily arise. Furthermore, the production department wants standardized series adapted to production units, while the marketing department wants to fulfill the demand from consumers and sees the value of having small, customized production series. Hence, the variant gap and quantity gap are also reflected here, which gives an additional argument for introducing a hybrid printing solution.

Shorter product series & faster updating

Customisation of information implies more versions designed for different market segments with the consequence of smaller volumes demanded for each version. Results from paper I indicate that it can be useful to run campaigns more often and that a trend is for companies to demand smaller and smaller quantities of packaging since the assortment changes more often. A digital printing unit integrated inline for customisation of information would open up possibilities to meet these demands for shorter product series.

Another important issue addressed by Dielemans (2001) is the importance to provide prototype packaging of new introductions at an early stage. Otherwise, the filler has a high risk of getting packaging that sells badly on the market. This is yet another driving force towards introducing a system where it is possible to customize information on the packaging continuously and create quick updates.

Almost all the respondents in paper I claim that the needed volume of packaging is widely variable. The companies are generally trying to avoid holding large stocks of packaging, but in order to get a viable price per package, rather large quantities have to be ordered. This variable demand indicates that an uncertainty factor exists that can likely be reduced with a hybrid printing solution. Since a trend is to order shorter and shorter runs, this problem would also likely increase.

Results in paper I indicate that new designs (within the food industry) might have a major affect on sales and that target-specific information can make a packaging more appealing to the consumer. Faster updating of product information and design could therefore be a way to gain market advantages. It is, however, important that the customer recognize the products on the shelf, which means that it can also be risky to change established designs. One way to increase sales without removing the products' marks of identification could be to customize only certain parts on the packaging, which is what Dante and Karles (2001) also suggest.

Hence, the demand for shorter production series and faster updating of packaging information is increasing, which also increases the need for a flexible production system. I believe that it is possible to look at the opportunities of customisation not only as a way to tailor information for different customers by making several versions of packaging with different specifications, but also as a way to tailor information toward different demands across time (see figure 10).

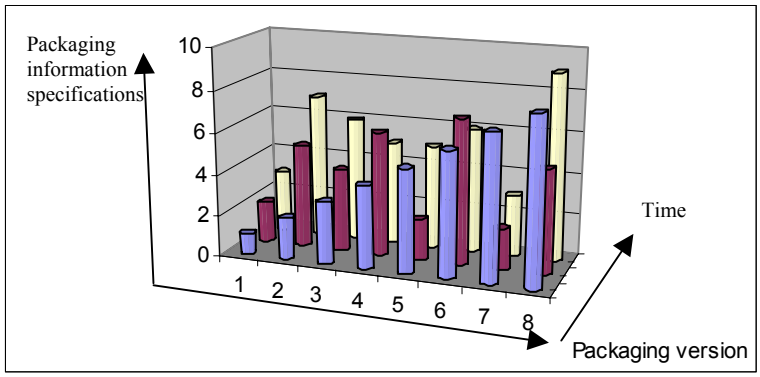

Figure 10. Example of customized packaging versions that are provided with different information depending on when in time they are produced. The figures have no other meaning but indicating that there are different packaging versions on the X-axis and different specifications on the Y-axis. The Z-axis represents time.

6.2 Limiting factors

Findings in paper I within the pharmaceutical industry show that authorities have to approve changes to a packaging design, which can be very time consuming. This limits the use of a flexible printer system. Furthermore, findings in paper I show that the producer's responsibility for his products limits the possibilities to customize pharmaceutical products later in the value chain. This means that it could be difficult to make fast changes according to changing market demands, but on the other hand, provides the possibility to make fast changes between different versions if you already have a number of approved packaging designs and a digital printing system.

It is stated in paper I that security, reliability and exactness of printing is crucial especially within the pharmaceutical industry. There must be no printing errors, since these could lead to serious consequences for a patient. These reliability demands will have an affect on the way a digital printing device can be designed and integrated into a packaging line. There will, for example, be a need for a system that is able to verify the correctness and ascertain the quality of the print.

It is also stated in paper I that packaging can be very price sensitive, which means that cost is a very important parameter to consider when a customisation task is to be introduced. Food packaging especially needs to be kept to a very low expense. Paper I shows that some companies find it expensive to consult designers and copywriters, which might limit the way the customisation task can be performed. The value adding opportunities achieved by customizing information on packaging discussed in the papers must at least offset the higher costs. That a higher cost could be offset by adding value to the product is exposed by Olsmats (2002) when he shows that product information has been ranked to have almost the same importance as a low price and that older people seem to be willing to pay for adequate information. The cost for ink in digital printing equipment is still very high, which means that it easier to make the printing of smaller sections of a package economically viable. Hence, a hybrid printing solution is an interesting alternative. However, Dante and Karles (2001) state that significant development and investments are necessary before the technology is mature enough to use, which strengthens the findings in paper II where it is stated that every new installation of inline inkjet printing involves a great deal of specific testing. Hence, start-up costs could be considerable and will definitely constitute a limiting factor to introduce a digital printing system. Since such installations are in their infancy it is very difficult to make accurate estimations for the cost of having a customization task. The inline printing solution at the studied company in paper III confirms, however, that inline printing in a packaging line can be done successfully. It should be noted that studied companies in paper I claimed that more versions would lead to complex logistics with a higher risk for incorrect shipments.

Olsmats (2002) states that one of the main improvement areas for packaging is to provide information that is clear and easy to read. Hence, an important remark is that it could be possible to make improvements working with design only and without any customisation activities. It is important to understand that many factors influence a product's consumer- and market value and that customisation of information on the packaging is only one.

6.3 Logistics

Concluded from the research papers as well as from other related research is the existence of a demand for customized information on packaging. There are several driving forces for this demand as well as factors limiting the realization of a business concept using customized information on packaging. These driving forces and limitations will affect the way the production workflow and logistics can be designed. An important remark, however, is that the opportunity to improve the production workflow by introducing a digital printing system is a driving force itself. The conducted case studies are focused on the second scenario, which is having the digital printing task performed at the producer. This implies that explicit investigations of the first (customisation at the packaging producer) and third scenarios (customisation at the wholesaler/retailer) are left for future studies. The received results have, however, given some input to the other scenarios, whereby it has been possible to discuss them as well.

It is shown in papers II and III that a digital printing solution integrated inline into a packaging line has the potential to reduce costs and decrease stock levels. It seems likely that it would be possible to also increase the receipts through the opportunity to offer specific packaging for specific customers with a satisfactory delivery service. According to Stock and Lambert (2001), it is possible to adjust the market price as long as the customers are willing to pay for better service. Olsmats (2002) shows that older people especially seem to be ready to pay for adequate information on the packaging. The studied producer of reams in paper II had many customers that wished to have their own packaging. Therefore, with a digital printing solution it would be possible to create a business concept in which all three ways to improve profitability according to Lumsden (1998) could be successful.

The installation and running of a digital printing system is however associated with additional costs that have to be put in perspective to potential gains. As stated by Lumsden (1998), all three factors are dependent on each other. A consequence of having a customisation task leading to higher receipts could likely be an increase in costs. Besides investments in the digital printing system, results in paper III show that it might be necessary to make additional investments to adapt the packaging line. It is likely necessary to invest in systems for supervision and removal of defect prints. According to Person and Virum (1998), the function of the production (which might be affected by a digital printing unit) constitutes a very important condition as to how the distribution systems

can be developed. Hence, it is crucial to uphold a high productivity in the packaging line to get effective logistics. This is also highlighted in figure 6. Among the elements required for success for an inline printing solution, defined by Dante and Karles' (2001), is found the importance of print quality matching the current standards, operator issues and reliability aspects, which strengthens the findings on critical productivity-related factors in paper III. Dante and Karles' (2001) also emphasize that equipment should be easy to replace and upgrade.

6.3.1 Location of the customisation task

The demand for flexible handling of products and faster updating of information on packaging and the associated costs (concluded in paper I) will affect where in the value chain the customisation task is best performed.

It would be relevant in this thesis to introduce the notation *packaging print to order* (PPTO) and relate this activity to the order penetration point. An interesting opportunity could be to use a make-to-stock strategy (MTS) for the products (optimizing production) complemented with a PPTO strategy to differentiate the products through the packaging. Hence, large-scale advantages in the production could hereby be combined with customisation of the information on the packaging. This would be applicable for the defined scenarios 2 and 3 in paper II.

In the value chain shown in figure 4, the packaging supplier (packaging producer), the producer and the wholesaler/retailer are the chosen actors in the scenarios where the customisation task can be inserted. When comparing the wholesale dealer with the retailer, it seems more interesting to perform the customisation at the retailer since he is closest to the customers and is in direct contact with the consumer. This in line with Stern and El-Ansary (1992), who state that postponement promotes efficiency by having customization closer to the time of purchase, when the demand is more certain. Therefore, customisation at the wholesale dealer will not be further discussed here. Since scenario 2 (customisation at the producer) is explicitly investigated in this thesis, the following analysis begins with this scenario.

Customisation at the producer (scenario 2)
The order penetration point would be at the producer (filler) for scenario 2. By having the customisation task performed here, the order penetration point can accordingly be shifted forward in the value chain from the packaging producer to the filler without losing the opportunity for customisation of information on the packaging. The stock level of different basic packaging versions would be decided by a prognosis (assuming that a hybrid printing solution is applied) while the packing and customisation task would be demand driven, initiated from a customer order. For the investigated company (U2) in paper III, the customized information was printed onto blank packages, which means that they only had to keep stock for one packaging version. It is also possible that a company itself could initiate the packing and printing for campaigns in order to push products with specific packaging designs to the market.

Both the production and packaging processes can be triggered by a customer order if the order penetration point is at the producer. Alternatively, only the packaging process is triggered if the products are already produced according to a prognosis. The latter alternative could be interesting if the production process is time consuming, meaning that the company could get a reduced delivery lead-time. By applying the first alternative it is not only possible to customize information on the packaging depending on the specific producer and product, but also possible to customize the product itself. Hence, such customized products could then be provided with matching information on the packaging, which provides another argument for scenario 2.

As concluded in paper II, there are factors indicating that the customisation task in general is best performed at the producer. This confirms Dante and Karles (2001) who claim that a digital printing task incorporated into the final packaging step is the most flexible way to customize information. Mitchell (2001) also says that inline printing of packaging would give the greatest benefits. It is possible to install printer heads along the packaging line when packaging material is continuously fed, which means that printing can take place without any additional manual handling of the packaging.

Johnsson (1998) states that it can be a complex task to integrate packaging and logistics. Dominic (2004) further shows that there have been problems conveying information about consumer demands to the packaging supplier. However, if a customisation task is performed at the producer in order to adapt information to customer demands, this lack of communication should be less severe. Hence, another driving force to introduce a customisation task is to avoid this existing communication gap. It is important to remark that other demands, such as preferences of packaging size and preprinting is still dependent on good communication between these actors. I believe however that an introduction of a digital printing system at the producer could be one way to facilitate the integration of packaging and logistics.

It is discussed in paper III whether to print before or after the packaging is filled. One of the case studies showed that the design of the existing packaging line is decisive for where the print can most easily be performed. Large investments are often made in packaging lines, which means that redesigning could be considered too expensive. Otherwise, it is concluded in paper III that printing is best performed before the packaging is filled. Mitchell (2001) strengthens this argument when he concludes that it is difficult to print on already-filled packages because of the vibration and dust factors. A customisation task just before the filling process is accordingly the location closest to the end user not requiring that information be added on an already folded and filled packaging.

With the customisation task at the producer, it would be possible to customize information towards different segments of customers, for different campaigns and specifically for different retailers. Customisation towards specific individuals could be more difficult to perform. Because one-to-one marketing requires that customers be identified before any customisation can be made, one-to-one marketing based on a customisation task at the producer could be difficult to perform for the studied lines of business. Hence, one-to-one marketing might require that the customisation task be performed even closer to the customer.

Customisation at the retailer (scenario 3)
Paper II discusses that a customisation task can be performed even closer to the customer when exclusive products are to be sold, which I believe gives better opportunities for one-to-one marketing. A movement of the order penetration point downstream to the retailer would limit the possibilities for customisation of the product, but by having a digital printing unit, the packaging could still be customized and adapted towards different customers. The extra handling needed to perform the customisation task for low margin products would however likely be too expensive, especially if secondary packaging has to be removed from the primary packaging before any printing can be performed. It would also be necessary to perform the printing on already-filled packaging without feeding it from a conveyor belt that is found in a packaging line, which might be inconvenient and expensive. When thinking of alternative solutions, an attached label could be one possible way to customize information on packaging at the retailer. It would, for example, be possible for a cashier to print and attach a label (digital printing based on database information available when the customer is identified through his/her affinity card) onto packaging at the check out counter. Paper I shows that the producer's responsibility for his product will limit the opportunity to perform customisation of the information on the packaging at the retailer within the pharmaceutical industry. More research is needed to evaluate how labels could be utilized and to confirm the discussion above.

Customisation at the packaging producer (scenario 1)
Customisation of information at the packaging producer might be advantageous in certain situations, for example, when the product filler gets customers that demand specific information on the packaging. The costs for an in-house installation that will likely require a lot of initial specific testing and achievement of necessary in-house competence would likely be considered too high in the beginning if the market demand for customized information on packaging not yet has stabilized. Therefore, it could be convenient to buy packaging customized specifically for the customers from a packaging producer. This could accordingly be a cheap way to conclude whether this business concept is successful or not. For a hybrid printing solution with a digital printing unit inline with a conventional press, the print speed will be much higher compared with the speeds of a typical packaging line, which set higher demands on the printer units, making it more challenging to achieve good print quality. As earlier described, the company Packaging Genie offers packaging with customized information and adapted size with a delivery time of four days (using solely digital printing). Hence, this solution would not be as flexible as having a digital printer unit integrated inline in the packaging line, but it is probably sufficient in some business cases. There is, however, a likely risk that the delivery costs of frequently sending small quantities of packaging to the filler could become too high to keep the packaging cost at a reasonable level.

Remark about intelligent packaging
Not discussed in this thesis are the possibilities with intelligent packaging that might in the future contain a display showing changeable information. One hypothetical scenario for food packaging could be that something in the consumer's kitchen triggers a display (assuming they exist at a reasonable price) on the packaging to show specific information. This display might be printed onto the packaging somewhere in the value chain. This way of customisation would be closest to the customer, but it is out of the scope for this thesis to investigate whether this scenario would be realistic.

6.3.2 Delivery service

Since customer service is claimed to be one of the best methods to gain competitive advantages (Stock and Lambert, 2001), it is interesting to further analyze how a digital printing solution can affect customer service. Since delivery service is a subset of customer service and is easier to specify in a concrete way, the delivery service has been further analyzed below for the investigated scenario 2. Improved delivery service is also a way to improve the external efficiency. This analysis assumes that the market will demand many packaging versions, which is according to earlier mentioned trends. Without a demand for many versions, a customisation task might not be motivated, which means that this analysis would not be relevant.

Delivery precision

Having the customisation task at the producer could be one way to assure good delivery precision when the number of packaging versions becomes too high to keep safety stocks for all versions at a reasonable cost. If the needed packaging version is missing, operating the conventional way without any customisation task, a lot of time could pass before the packaging producer is able to deliver. Provided that a reliable printer unit is standing in a room at the producer with a normal constant climate, the risk of a lack of a specific packaging could be decreased if the basic packaging designs are customized to the right versions whenever the demand arises. Having a customisation task at the producer will, however, demand that the productivity in the production/packaging line is high enough to assure a satisfactory delivery precision even if many customer orders are received at the same time. Hence, there is a need to have good capacity flexibility; otherwise, delivery precision could deteriorate.

As shown in paper III, it is very important to consider the reliability aspects of the printer system in order to assure a high productivity. If the printer unit breaks, serious delays can arise unless fast repair and service is available. Hence, the reliability of the printer is crucial for the delivery precision. The level of operator qualification as well as preventive maintenance would have an influence here. Paper III shows that the printer unit and the packaging line have to interact properly in order to assure high productivity for an inline solution. Start-up time, sufficient over-capacity and reliability issues at the packaging line are important factors to consider. An important remark is that the studied printer systems were relatively newly installed, implying that teething pains were rather common in the beginning. Besides these teething pains, that in consecutive order have been fixed by the companies, the number of printing failures were relatively small. For company U1 nozzle failures appeared two times per hour. It is however shown in paper III, that print quality demands will affect the number of stoppages of production.

Delivery safety
Delivery safety can be affected by the integration of a digital printing unit in a packaging line. The inline printing would make it possible to easily adapt information on the packaging after the customers' requirements. Since packaging can be seen as a part of the purchased product, print quality and correctness of printed information are crucial for the delivery safety. As stated in paper I, the correctness of print is of crucial importance within the pharmaceutical industry. According to the results in paper III, print quality and reliability are important issues that need to be put into focus. With lower demands on print quality as for company U2 in paper III (selling products to business customers), it will be easier to assure a high delivery safety. Findings in paper III show that a problem related to print quality is variable substrate quality. Concluded in paper III, as well as by Mitchell (2001), is that the quality of corrugated board varies, which has an impact on print quality and sets demand on the printer system. Other critical issues identified in paper III are to assure that print quality is supervised and that there exists a system to remove misprinted packaging. Hence, a digital printing task could have a negative effect on delivery safety. The opportunities for customisation could, on the other hand, make it relatively fast to correct eventual misdeliveries.

Delivery rate
Customizing packaging before delivery through a hybrid printing solution means that it is not possible to deliver directly from stock once an order has been received from a customer. Having a business concept where information on packaging is customized towards specific customers could accordingly impair the delivery rate. It is not possible to have a buffer stock if every single package is to be customized, but whether there actually would be a need for customisation of every single package could, of course, be a matter for discussion. With a growing demand for more versions of products, it would more likely be very expensive to keep all different types of products in stock in order to assure a high delivery rate. Delivery lead-time could be improved to compensate for a deterioration of delivery rate.

Delivery lead time
Paper II shows that the delivery lead-time could be shortened considerably by having a hybrid printing solution performing the customisation task at the producer. As mentioned earlier, the order penetration point can be shifted forward in the value chain from the packaging producer to the filler without losing the opportunity for customisation of information on the packaging. It is possible to decrease delivery lead-time by moving the stock closer to the customers, presuming that the demanded products are found in stock. With the opportunity to customize products by adapting the printed information on the packaging, it would be easier to assure that demanded products be delivered on time, without the need for a considerable level of stock. Further analysis of costs for stock keeping of semi-finished products and the costs for having a customisation task would, however, be needed to conclude whether a hybrid printing solution would be economically viable or not.

When lead-time can be shortened, it would, according to Aronsson (2000), be possible to shorten the delivery time or increase the capacity flexibility. If all packaging is to be customized by digital print, the capacity to deliver on time is dependent on the capacity (speed) of the digital printing task and on the actual order stock. It would be advantageous to have good capacity flexibility to assure stable delivery times since it then would not be possible to keep stock of finished products,

Flexibility
Paper I indicates that it is rather common within the pharmaceutical industry to have a last minute panic at the production site since texts from marketing companies are often delivered very late. Faster updating of information on packaging through a flexible production system would therefore be convenient. Dante and Karles (2001) also state that production schedules change frequently and often at the last minute. Respondents in paper I claim that it is common to have marketing of other products on the packaging (cross-selling). A digital printing solution makes these efforts to cross-sell more flexible.

The research described in this thesis show that the use of digital printing can help a company become more flexible in providing customer specific products in the right quantity at the time when the market demand arises. The technology gives better opportunities to control **what** information is to be added onto the packaging and **when**. Compared with a conventional printing process, a digital printing unit is rather small and less expensive, which means that it could be economically viable to install such units at several geographic locations. However, they are still rather expensive and, as discussed in paper II, a lot of manual handling would likely be required, which means that it would probably only be suitable for exclusive products with high profit contributions. It would be possible, however, in a hybrid printing solution to use such units to add customized information on pre-printed packaging. Hence, digital printing may also imply a possibility to decide **where** information is to be added, which may improve a company's nearness to customers. When the parameters when, what and where are controlled, I believe a company creates potential to get an increased market share through timing and customisation (see figure 11), which can also be seen as a reduction in the gaps between producers and consumers defined in the marketing channels literature.

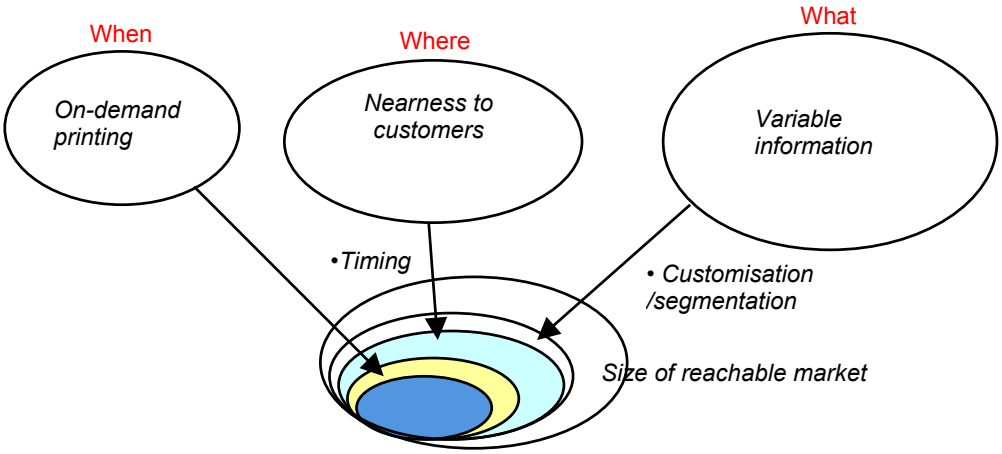

Figure 11. A hypothetic model of the potential to get increased reachable market size through flexible printing

Delivery service –final comments

A satisfactorily delivery service is important to have to maintain a good business. Improvements of the delivery service are possible to obtain through a hybrid printing solution. However, it is of crucial importance to consider the possible drawbacks to assure that the expected improvements to delivery service don't prove to be deteriorations. I believe that there are not only small improvements to an existing production solution that can be obtained. A hybrid printing solution could imply a new production strategy that may lead to considerable reductions in the existing gaps between producers and consumers.

6.3.3 Productivity and efficiency

A number of factors have to be considered to assure high productivity in a packaging line when a customisation task is integrated. Critical productivity related factors are identified in paper III. As shown in figure 6, productivity is directly related to efficiency. It is shown in the previous section that it is possible to improve the delivery service and thereby the external efficiency through a hybrid printing solution, even though possible risks need to be carefully considered. It is obvious that the productivity related parameters, identified in paper III, affect the delivery service and thereby the external efficiency, which is according to the workflow in figure 6. It would also be possible to improve the internal efficiency by using a hybrid printing solution. Paper II shows that stock levels could be reduced without increasing the risk for running out of stock, which means that material handling could be improved. It is however important to remark that eventual increased cost (not covered in this thesis) could will impair the logistical efficiency.

7 Conclusions

In this thesis a number of factors, important to consider to evaluate whether potential gains will offset eventual disadvantages in the customisation of information on packaging, are identified for a hybrid printing solution. It is shown that it is possible to reduce gaps between producers and consumers and to improve logistics and specifically, the delivery service. The importance of considering possible drawbacks is also emphasized.

Lumden's (1998) model (figure 3), focuses on logistics. In addition to delivery service (regarding the increasing of receipts), I have chosen to modify this model to also include marketing aspects to structure my conclusions. The most important driving forces and limiting factors concluded through my research are shown in figure 12. There could also be other important components not discovered in my research and the importance of the identified forces and factors might be dependent on the specific business case. Johnsson (1998) states that most companies view packaging as a cost driver and do not consider the potential benefits involving cost savings in the value chain, which means that there is a need to highlight potential benefits in relation to costs and eventual disadvantages. A comment on figure 12 is that *delivery service* is highlighted on both sides of the tilting lever. As discussed in the analysis, there are opportunities for an improved delivery service through introduction of a customisation task, but there is a risk for impairments at the same time. A major investigation might be needed before a company can conclude whether the introduction of a customisation task would be successful or not.

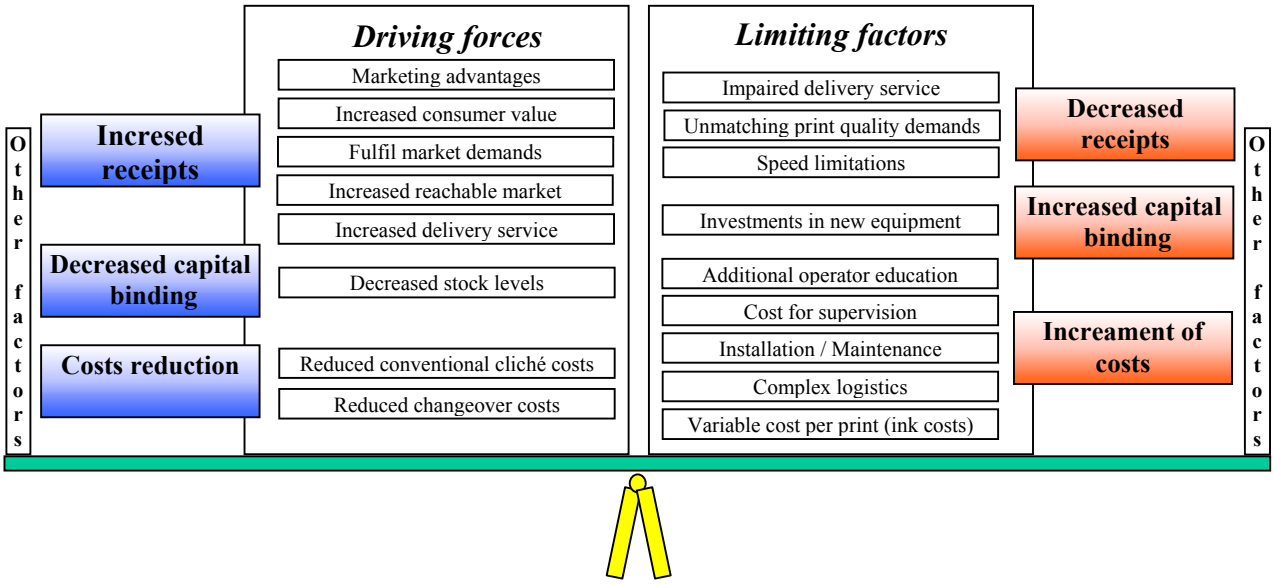

Figure 12. Driving forces and limiting factors in the customisation of information on packaging using a hybrid printing solution.

It is furthermore discussed how a customisation task should be performed in order to obtain efficient logistics. It is shown that there are factors pointing at the second scenario (having the digital printing performed at the producer) as the most beneficial location of the customisation task in many situations. The order penetration point can be moved downstream to the producer without losing the opportunity for customisation of the information on the packaging. There is still, however, a need for explicit investigations of scenarios 1 and 2 in order to get a complete picture of the benefits and drawbacks of these scenarios. As shown in paper III a number of critical factors are important to consider in the second scenario in order to get a high productivity. With high productivity it is also possible to obtain a high delivery service and thereby an efficient logistics, even though eventual increased costs and drawbacks need to be carefully considered. I believe that there is a need for much development before inline customisation of information on packaging will be used extensively.

7.1 Future research

Printing performed inline on a packaging line implies a risk for production stops should anything in the printing process fail. An offline solution could be an interesting alternative when short series, that do not need full flexibility or the need to customize every single package, are sufficient. Potential problems (identified in paper III) related to the integration of printing in the packaging process would then disappear. More research is needed to fully evaluate this scenario. Mitchell (2001) claims that offline printing at the filler appears to be an ideal positioning.

The studied paper producer in paper II had started to add labels onto pre-printed packaging in order to reduce the number of basic packaging versions. This has also been applied within the food industry for small markets when it has been considered too expensive to produce specific packaging by conventional print technology. This way to customize information is an alternative to printing directly on the packaging. A few comments from respondents within the food industry has been that labels can come loose in the frozen-food displays and that it might look more professional to print directly onto the packaging. This would of course, however, depend on the packaging design and the actual field of application. A lot of packaging is designed to have labels attached. Mitchell (2001) says that labels are a straightforward way to customize packages, but that the main disadvantage is the cost. Labels are widely used today and it would be very interesting to conduct more research on these possibilities and to compare costs, advantages and disadvantages between the use of labels and printing directly on the packaging.

When printing technology develops even further and the ink for digital printing equipment becomes less expensive, it would be interesting to investigate where a hybrid printing solution is applicable compared with using only digital printing equipment. It

has not been possible within this study to make any direct comparisons expressed in monetary values between additional costs and the added value provided through customized information on packaging. It would be very interesting to get such figures, even though it might be difficult to measure the consumer value. A comprehensive investigation would likely be needed.

It would also be interesting to investigate how the information on the packaging could interplay with other information channels in order to attain good relations with the consumers, e.g. through one-to-one marketing.

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Included papers

Paper I

Customised Information on Packaging – Business Opportunities and Consumer Value

Magnus Viström*, M.Sc

Keywords: Packaging, customisation, market value, consumer value

Abstract

Customised information on packaging could give the consumer a higher product value. Individualised instructions or customised marketing messages based on a customer profile can be an efficient way of increasing the value of a product. Using digital printing it is possible to produce tailored editions of packaging for different regions or separate versions for each supermarket. Theoretically, it is possible to individualise every single packaginge. Hence, the use of digital printing makes it possible to offer products in new ways. However, it is necessary to consider carefully the pros and cons. Legal, ethical and economical issues may counterbalance the possible benefits. This paper presents a study, based on qualitative research and interviews with several Swedish companies within the food and the pharmaceutical industries in Sweden. The study highlights many potential benefits of customised information, but at the same time the results indicate that legal, ethical and economical issues are critical factors. The study provides a basis for further research, including end-user usability tests and workflow analysis for producing packaging with customised information.

1 Introduction

Technological developments within the graphic arts industry provide new opportunities to customise packaging. According to Loutfy (2002), the new business imperative is a move from make-then-sell to sell-then-make. Sarelin (2001) claims that there is a considerable need for personalised packaging for small-scale campaigns in different countries and in different markets. As packaging will be available to an increasing extent in larger markets with different languages and different cultures, Nilsson and Hermansson (2000) claim that the demand for high quality information on packaging will increase.

In order get knowledge about driving forces for using customised information, an investigation of Swedish enterprises are made. In order to give a wide perspective on the issue, two lines of business working under fundamentally different conditions are studied. The food industry is competing in stores on a mass market while the pharma-

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ceutical industry is representing another category, where formal demands, security and legal issues are important. High usage of packaging and strong competition between companies, with many of marketing activities, makes packaging and the opportunities for the customisation of information very interesting for the food industry. Each year the Swedish people consumes food (beverages included) at a cost of about 2400 USD per person with food packaging making up 50 % of the cost (1,5 billion USD) of packaging material in Sweden (Dominic, 2000).

Within the pharmaceutical industry, it is very important that the printed information on packaging is 100% correct as wrong information could lead to serious consequences for a patient. The cost of under-dosing, over-dosing and mis-dosing pharmaceutical products in US is estimated to more than 100 billion dollars per year and is a leading cause of death (Valdes, 1998). It is estimated that 106,000 Americans died during 1998 because of adverse drug reactions (Brady, 2001). As people respond individually to different substances and need different dosages, individualised instructions are of crucial importance. Progress in medical research is also making it possible to get individual drug reaction profiles of patients.

The consumer should also be instructed in a convenient way about the use of the pharmaceutical product for different symptoms. According to Rosenblad and Pousette, (1997) pharmaceutical packaging is handled by different users in different environments, which means that there is a diversified need for different designs of packaging. As the number of elderly people in the Western World increases, health care at distance, with a growing need for customised information, is predicted to be a prerequisite for coping with the increased cost of nursing care (Olsmats, 2001).

Digital printing provides new possibilities and new markets for printed matter. The technology implies that a piece of printed matter can be produced at a desired point of time and in the desired quantity (print on demand). As digital printing makes it possible to individualise every single piece of printed matter the theories for one to one marketing and segmentation can be useful for developing interesting business opportunities.

As a product cannot appeal to every buyer it is advantageous to identify market segments and develop products and marketing mixes in order to focus on customers that more likely will buy the products. Hence, segmentation is a compromise between mass marketing and one to one marketing (Kotler, 2001).

According to Kotler (2000), one-to-one marketing can lead to the capturing of market shares, customer retention and improvements to customer satisfaction, together with an increased return of investment. Using one-to-one marketing, the focus is on each individual customer whereby companies can differentiate not only the products, but the

customers as well (Peppers and Rogers, 1993). As stores get information about their customers through affinity cards it would be possible to identify customers who visit the store frequently and differentiate them according to Peppers & Rogers' (1999) segments: *most valuable-*, *most growable-* and *below zero customers,* and according to their purchasing profiles. Theoretically this means that the store could provide valuable information about how the packaging could be designed in order to give the customer added value or to improve campaigns or marketing opportunities. This information can be addressed both to the companies representing the A-brand segment and to their own suppliers of packaging (private brand segment).

> *An A-brand product is a product that is produced by a company and sold to different stores and companies. Private brand products are products that are produced and sold by the multiple chain stores themselves*

Hence, there are many interesting possibilities for customisation and the use of digital printing within the food and pharmaceutical industry. However, it is of crucial importance to understand the driving forces for using customisation for those lines of business, which brings us to the purpose of this paper:

To contribute to the knowledge about driving forces in the customisation of information on packaging

This study is focused mainly on the outer consumer packaging that is used for food products in supermarkets and shops in Sweden. Within the pharmaceutical industry the focus is on the outer packaging that is sold at pharmacies, but the "product packet insert" (text information on a sheet of paper) is also included in the study as it contains most of the instructions. In order to fulfil the purpose the following research question has to be answered:

What are the driving forces for using customised information on packaging within the food and pharmaceutical industry?

2. Lines of business

Food industry

> **References**: PBx = Private brand company x, Ax = A-brand company x, Mx = market company x DPx = producer of dairy product x

The production of agricultural and foodstuff in Sweden was during 2000 worth more than 11 billion USD and the number of everyday commodity shops 2001 was 6268 (Livsmedelssverige, 2003).

Suppliers of food for consumers sell their products to multiple store chains in Sweden and to companies abroad. Many of the products are sold to wholesalers, who in turn sell

the products to the stores. In addition, food corresponding to 49 % of food consumed is sold to the food service segment (Wallteg, 2002). Apart from a basic line, each store can chose its own stock and in that way customise their selection of products to local needs (PB1).

Pharmaceutical industry

References: P1 = pharmaceutical company x, PMx = (pharmaceutical) market company x

In 2001, the value of prescribed pharmaceutical products was 2.5 billions USD, the value of medicine sold directly to the hospitals was 410 millions USD and the value of products sold over the counter was 235 millions USD, (Swedish Association of the Pharmaceutical Industry, 2002). In 2002 the number of consumer pharmaceutical products in Sweden was 4443. A further 1150 were imported. After the pharmaceuticals are produced at a production site, they are packed and shipped to different market companies. In Sweden and many other countries the regulations for pharmaceuticals are very strict and all pharmaceuticals have go to through the pharmacy before they can be sold to hospitals or consumers At any one of the 865 (Apoteket AB, 2002) pharmacies in Sweden, customers can buy their prescribed pharmaceuticals or buy products over the counter, OTC. Aptoteket AB (the union of all pharmacies in Sweden) is trying to identify the customers' needs at pharmacies (AP, 2002). For the prescribed pharmaceuticals the physician informs the patient about the product. The pharmacist has a control function and checks that the dosage is realistic (P5). In addition to the information printed on the packaging, each packet must contain a "product packet insert". This gives basic information about the pharmaceutical product, user instructions, different kinds of indications, side effects and active substances. The pharmacies cannot alter this printed material but they can supplement this information with more general brochures (AP, 2002).

3. Methodology

A qualitative cross-section study based on unstructured interviews was made during 2002 and 2003.

Choice of companies & respondents

Food industry

Among the largest food manufacturers of A-brand products in Sweden (turnover > 55 million USD) four companies have been chosen at random from the database (Affärsdata, www.ad.se). In addition the three largest private brand companies in Sweden (>90% coverage of the Swedish market, Kindvall, 2002), two of the three largest manufacturers of dairy products and one marketing company without any production units were selected. The division into these different segments was made in order to cover a broader population and to see if additional information would be found. All companies have a turnover of 55 million USD or more. The respondents were

marketing managers, product managers or those responsible for packaging, and a common factor for them has been responsibility for, or strong involvement in, marketing and packaging issues.

Company	A1	A2	A3	A4	M1
Position of respondent (s)	**R**esponsible R & D (Formerly marketing manager)	**P**ublicity manager	**M**arketing manager, **P**urchasing manager	**M**arketing manager	**R**esponsible packaging department

Company	DP1	DP2	PB1	PB2	PB3
Position of respondent (s)	**M**arketing manager	**R**esponsible for packaging, (formerly at the marketing department)	**P**rivate brand manger, **R**esponsible packaging	**P**roduct manager	**M**anager for 2 trademarks

Pharmaceutical industry

Five companies with manufacturing sites in Sweden (turnover > 5 million USD) were selected at random from the pharmaceutical industries in Sweden (from the Affärsdata database). The largest pharmaceutical company in Sweden, one small company producing one expensive product, and two marketing companies chosen at random complemented this selection. This additional selection was made in order to cover a larger group of different respondent, in order to get additional information. Two persons (MPA1, MPA2) at the Medical product agency and one person (AP) at Apoteket AB (the union of all pharmacies in Sweden) are also included in the list of respondents.

Company	*P1* ***(largest)***	P2	P3	P4	P5
Position of respondent (s)	**R**esp. Labelling regular affairs, **M**anager for product development, **E**mployee at packaging department	**M**arketing manager	**R**esponsible for Packaging Department	**M**arketing manager	**P**roduct manager, **R**esponsible for material

Company	P6	**P7** (1 prod.)	PM1	PM2
Position of respondent (s)	**M**arketing manager, **S**upply chain manager	**M**arketing & sales manager	Coordinator regulatory affairs	**P**ackaging & design

Data collection

The study is mainly based on primary sources (respondents at the selected companies and respondent at other important bodies such as the Medical Product Agency). In addition, secondary sources (books, articles, Internet) are used to get information about related research and to collect interesting theories for use in the analysis. For the first five interviews, I visited the respondents at their companies. Unstructured interviews were used in order to find interesting themes to base the subsequent interviews on. The

identified themes were information on packaging related to the consumers' needs and retailers requirements, marketing aspects, and limitations. Based on the identified themes supplementary telephone interviews were made. Within the framework of the specified themes, the respondents were free to express their feelings. When necessary, respondents supplemented their information by questioning people in the company. After the interviews follow up phone calls were made whenever something had to be clarified.

4. Collected data

The presentation of the data is structured according to the identified themes.

Consumers demands and needs - food industry
Most companies (private + A-brands) do not experience any direct demand from consumers for customised information on packaging. However there could be a need for additional information on packaging in some countries or local markets (A1,A3). In some countries, reading comprehension is poor even in the local language, which means that more symbols (A3) could be used. It would also be useful to highlight important parts of the text, as they can easily be overshadowed by other information (A3). Consumers have a general interest in knowing the origin of food products, which means that it is useful to add the name of the local producer on the packaging for local products (A3). Another example is to offer washing powder, with the local conditions for pH value and hardness being indicated on the packaging (PB3).

Consumer demands and needs - pharmaceutical industry
It is useful to offer products that make it possible for elderly people to stay at home rather than in hospital (P7). Within the pharmaceutical industry, there is a need to educate and inform consumers better (P6). There is usually not enough space to include all information on the "product packet insert" since there are so many instructions (about what you can eat together with the medicine, different side effect etc.) (P5). American pharmaceutical products are often supplied with a great deal of information about all kinds of side effects, in order to be on the safe side with respect to legislation (AP, 2002).) The requirement for information is different for each individual (MP1 (2002). If a person is about to take a medicine for the first time, he has a different need for information than a person who is familiar with the product (P5, AP, 2002). It might be useful to provide different information depending on the age of the consumer, as the need of information can differ between different age groups (P7). Pictures are seldom needed to inform the customer (P5).

Customers also find the "product packet inserts" boring and hard to read (P1, P5). According to AP 2002 they contain a lot of information that is not always well structured. Some people are also afraid of all the side effects mentioned (PM1). It would be desirable for the texts to be updated as soon as new knowledge about side effects is found.

Patients can find that the "product packet insert" contains too much text to read and that the text is not relevant. This means that the "product packet insert" can be confusing to the patient (MP1, 2002). According to MP1 (2002) the physician's verbal information can be hard to digest for the patient, especially in a stressful situation at the hospital. Therefore customised information on the packaging or on the "product packet insert" could be valuable for the patients. However physicians have more responsibility than companies to customise information for patients (PM2). If a patient is using a special medicine, it could be valuable to equip him with customised instructions, whereby a carer or nursing staff could read instructions about special conditions for treatment, if he/she should fall ill (P7). P5 think that it would be useful to customise different dosages and consumption times. P2 can see value in making specific packaging for specific companies that like to create a distinctive image. Sometimes packaging needs to be associated with a medicine while at other times it is desirable that the packaging looks neutral. A person might not want to reveal that he is taking a pharmaceutical product (P7).

Apotektet AB has four production sites where pharmaceuticals are customised for individuals or groups of individuals. This business stands for 2-3 % of the sold volume and there is an increasing interest in those products as it is possible to relate certain diseases to a person's genetic structure. Those products are linked to prescriptions and the physician is responsible to inform the patient about side effects. No ordinary product packet insert, ppi is used for those products. Earlier each pharmacy used their own laboratory to mix pharmaceuticals for different needs but as that is expensive the solution with productions sites anticipated for small series is very interesting (AP, 2003).

Demands from the retailers - food Industry

Earlier, customers of A-brand companies consisted of 4000 stores in Sweden (A4). Now, because of a structural transformation, the customers consist only of the three multiple chain stores, and these large players are putting pressure on the market with the intention of increasing their share of private brands (A3, A4). The multiple chain stores decide what brands to include in their stock (A3). The A-brand companies see no radical countermoves toward increasing their share of private brand products, besides being ahead and offering better products. One way is to create a news value by releasing products containing new primary products or ingredients, together with new information on the packaging (A1).

For A-brand companies, the possibility of using special stands and signs for marketing in the stores have almost disappeared, as the stores want to use their space more effectively (A2, PB3). This makes it very interesting to design the packaging for the store shelves in order to take over the function of those signs and special stands (A2). Several retailers in other countries are demanding that the names of the products shall

be saleable internationally and it can be a problem to find a suitable name, if the same language is used in several countries (A1). With a more flexible solution for printing it would be possible to customise packaging for different stores (A4). There has been no direct demand from the stores but company A4 says that they would most likely be interested in having versions of products designed for their specific shop, and thereby get a unique profile in order to take a position on the market. Company A4 is presently investigating the possibilities with fold out labels designed for local needs.

Demands from the retailers - Pharmaceutical industry
Some countries are demanding very specific solutions, which makes it difficult to meet their requests (P1). P1 has tried to supply unified packaging to certain countries, but now those countries are demanding separate versions (P1). According to P7, in the near future retailers might want their names on the labels. A new demand from Italy is to have serial numbers on a label, which is used by the consumer to get money back from the government (P3). Formerly there were more products with universal English text. Today most countries are introducing packaging with the printed text in their own language (P3). Up to five different languages can be printed on the packaging for prescribed pharmaceuticals.

Marketing - food industry
There is strong and increasing competition between companies in the food industry (A3, M1, A4) especially as competitive products from other countries are also being introduced into Sweden. Strong brands and quality products that the customers will recognise are necessary in order to compete against other companies (A3, DP2, A4). However, the products for different brands often have a comparable quality, which means that the design of the packaging becomes more important in order to differentiate the product (DP2). In addition, new designs often have a major effect on sales (PB1). To make the packaging more appealing to the consumer it would be useful to add target-specific information by a digital printing (A1, A3) and this customisation could be done at a later phase in the value chain, as you can then be sure that the information is up-to-date (A1,A3).

Packaging should be lively and packaging with a monthly theme and different messages could be useful (A3). Some of the cardboard packaging for perishable products has panel spaces (space on the packaging where text can be replaced frequently) that are changed regularly (DP2, DP1, PB3). To a certain extent, messages are designed for different regional areas, but most messages are the same for the whole country (DP1).

It can be useful to customise packaging for advertising campaigns (A1) and to run the campaigns more often (A3). According to PB1, only the A-brand companies are currently running advertising campaigns, but in the long term, campaigns will also be run for the private brand sector (PB1). It could be useful to provide advertising on the packaging (PB2) or to highlight a special ingredient (A3). It is common to have

marketing of other products (cross selling) on the packaging (A1, A2, PB2) and promotion packs and competitions are sometimes made in order to increase the sales (A1). The trend is that companies are demanding smaller and smaller quantities of packaging, as the assortment will change more often in the future (A4). This implies a greater need for faster updating (A4).

The respondents didn't have a lot of examples about customisation, but they said that it is normally very interesting to design information for different groups of consumers (A1, A3, A4). For marketing reasons, it can be useful to emphasise the use of some specific ingredients for special needs (A3). PB2 are working with different private brands for different groups of customers. In that way the selection of products will be designed for a few different target groups.

Marketing - pharmaceutical industry
Today, the cost of developing a new pharmaceutical product is high. There is a lot of research, clinical testing and adaptation to regulations. Formerly, pharmaceutical companies made large profit and they could therefore cope with high costs. Today as competition among companies is increasing there is a great interest in rationalization within the pharmaceutical industry (P7). Formerly, companies were competing with different pharmaceuticals; today companies are increasingly competing with the same type of pharmaceuticals (P1), which means that the importance of brands is getting stronger. When patents expire, new competitors enter the market, and prices are forced downwards (P3). In order to compete against other companies there is a need for attractive packaging and to add more value to products (P2, P5). One trend is that companies are increasingly focusing on colour (P5). Information and education is also a way of competing against other companies (P6). It is difficult for companies to influence the layout of products on the shelves in the pharmacies (P5), which means it is important to have the products clearly marked so that customers can find them easily (P1). Adding symbols to the packaging could be a good way of making the customers recognise the products better (P1).

The characteristics of the data made it convenient to present the data about limitations under the following headings: economical, logistical, ethical /consumer and legal.

Economical limitations - food industry
All studied companies say that packaging is very price sensitive and in order to introduce new features on packaging, the customer has to be given added value (A1). As the market in Sweden is small, customisation of products could end up increasing the price for the customer (PB1). If there is only a slight improvement in the product, the cost of the packaging should not be too high (A3, DP1). Perishable foodstuffs are particularly price sensitive (especially milk) (DP2). With respect to marketing there are other media (direct mail, advertisement) that are faster and perhaps more economical than information on the packaging (PB3) itself.

New designs for packaging are expensive (PB1, PB2, PB3). It is also costly to create panel spaces for some products, as this involves the work of copywriters and designers (DP1). Panel spaces on packaging are generally difficult to work with, as they are so small (DP1). When changing a design, it is easy to make small mistakes or fail to achieve the desired result, which means that even more changes are needed (A3).

Economical limitations - pharmaceutical industry
It is expensive to make packaging for a niche market, as smaller volumes of packaging (P1) are needed. The production of documentation is also expensive and whenever a product is changed in some way, updating of consumer and production documentation is required (P3).

The price of packaging is sensitive and sometimes 1 cent can mean the difference between making a profit or loss (P2). However, some of the pharmaceutical products are very expensive, which means that the cost of packaging is less important (P3).

Logistical limitations - food industry
More products and more frequent advertising campaigns mean more complex logistics and a higher risk of incorrect shipments (A1, A2,A3). If you don't have the right packaging at the packing stage you will have a stop in the production (A1). For many products it can also be logistically difficult to reach the right customers with the right versions of products, especially as all products are delivered through a central warehouse (DP2, A3). It is easier with perishable foodstuff as these products are often produced locally and sent directly to the stores (DP2).

Distribution and production factors have to be considered before a new product is designed and introduced onto the market (A1,A2). Conflicts between marketing and production departments can easily arise as the marketing department sees the value in having a short, differentiated series, while the production department wants standardised series adapted to production units (A2, A3, P1). Different suppliers of packaging have different ways of optimising the production and quantity required, as well as the choice of colours (DP2).

The market in Sweden is considered too small to have regional versions of products. Nowadays a local approach is uneconomical (DP1). Company A1 feels that the printed quantities would be too small and the cost per unit would be too high. This implies that packaging is often similar for different countries (A2). The broader the variety, the more opportunities there are for in-line printing (printing of information in the production line) (DP1).

Logistical limitations - pharmaceutical industry
An increasing demand for more versions and small volumes can be critical for logistics, production and stock keeping (P2). Texts from marketing companies in other countries are often sent in very late (P6) and it is common to have a last minute panic at the production site (P5, PM1). Problems with supplying the market fast with products could mean that new market shares in a country are not taken up fast enough, which is desirable to some extent since in the early stages small markets return a small profit (P2). There is also a big difference between texts from different companies, as many companies do not have an office in Sweden. In many cases the companies do not have the necessary competence to produce good texts, which makes it difficult for consumers to understand the information (MP1, 2002). The capacity to add information to packaging is limited because of the small amount of space available, with the packaging being used primarily to identify the pharmaceutical product (MP1, 2002).

For production purposes, it would be ideal to have a limited number of standardised packaging options that all countries could use (P1). P3 thinks that it would be a nightmare if products were customised, as they would get 100,000 pharmaceutical products instead of 500. The set-up time for production facilities is seldom less than 7.5 hours and according to the regulations everything has to be cleaned, even if exactly the same product is produced afterwards, but is used for a different unit number and packaging (P3).

Almost all respondents think that the volume of packaging required is very variable. Generally, companies are trying to avoid holding large stocks of packaging, but in order to gain large-scale advantages, large volumes have to be ordered (P2). Up to 200,000 units can be ordered at one time (P3). For economical reasons the minimum packaging order is around 5000 units (P1, P3, P6, PM1). The trend is to order shorter and shorter runs (P5).

When making an in-line print you must keep an eye on printed packaging. Computer systems have been criticised for making it too easy for someone to change the content of a database. It is then not possible to check all the packaging subsequently (P7).

Consumer / ethical limitations - food industry
Companies could not provide much information about ethical issues, apart from the importance of an environmental friendly profile and having 100% correct information on the packaging (A4, PB1, PB2, PB3). Companies that try to mislead consumers will only get a bad reputation (A4). It is important not to re-design too often, as customers must be able recognise products on the shelves (A3, PB1). Important information may be missing since ethical issues will probably arise if packaging is aimed at specific customers

Consumer / ethical - pharmaceutical industry
The respondents had few comments to make on ethical issues. After the legal considerations there is not much left concerning additional ethical aspects (P1). However, if some consumers do not want to reveal their need for medicine it is important to respect this (P7). AP (2002) claims that it is important to protect personal integrity. In some other countries the use of pictures and symbols is less restricted, which can be good from the marketing department's point of view. However, there is a risk that important information will be less visible if pictures for marketing purposes are printed on the packaging (P1). It is important to consider the customer's need to recognise the product, which means that the packaging design should not be updated too often (P2).

Legal limitations - food industry
Food legislation is common for all countries within the European Union (EU). The marking must not mislead the consumer, especially regarding the characteristics of the product, and the quality, quantity, origin, and production method. The product cannot be ascribed characteristics that it does not have. In general the marking must not contain any statements that the product will treat or cure illness. The information must be printed on the packaging or on a label attached to the packaging. The information must be easy to understand, clearly visible, readable, and permanent Information about the product designation, net quantity, use-by date or expiry date and alcoholic content must be displayed in the same field (National Food Administration, 1993).

Legal limitations - pharmaceutical industry
Within the EU, Council directive 92/27/ECC forms the basis of the legal issues concerning the design of packaging. Instructions about the storage and declaration of additives are the most important guidelines derived from this directive (P1). Pharmaceutical products that are approved by the EU may not be approved in other countries because of national regulations (P1). All marking on the packaging has to be approved by the Medical Products Agency (P1). Every time the packaging is changed it has to be re-approved (MP1, 2002). The design is strictly controlled and pictures are normally not allowed (P1, P2, P5). This is to ensure that the packaging for pharmaceutical products is simple and plain. The packaging must not be used for marketing (MP1, 2002).

The following information is required on the packaging: name of the pharmaceutical product, strength, batch number and expiry date, preparation of drug, address of the company selling the product, full dosage instructions (for OTC products) (P1). Pictures are permitted (both on the "product packet insert" and on the packaging) for explanations, as long as they are not there just to improve the appearance. (MP1, 2002). The "product packet insert" is based on a product summary and it would not therefore be possible to provide separate versions for each instruction (MP2 2002).

Updating takes time because of bureaucracy (P7). The fact that it can take six to twelve months to have a change approved, limits the possibility of making rapid changes to information on packaging (P2, P7). It is common for companies to make different pharmaceutical products with different strengths, but for each strength to be counted as a product in its own right (MP1, 2002).

As the producer of a pharmaceutical product is responsible for the product and the printed information, packaging information cannot be added later at the pharmacy (P5). According to AP (2002) pharmacies cannot take responsibilities for this. What happens if they forget to inform the patient about a side effect? The staff at the pharmacy do not always know what symptom the pharmaceutical is designed to treat, which may be due to the patient's unwillingness to reveal his illness or the fact that the doctor has failed to make a proper record in writing. The "product packet insert" must be added to the packaging by the producer. There could be a safety risk if this information is provided by pharmacies (MP2, 2002).

5. Analysis

There is a strong competition between companies within the food industry, and the importance of a strong brand and a high quality product is great. However, in order to compete, the design and the information on the packaging are also critical factors, especially as the quality of the products for different brands are comparable today. In general the companies are showing a large interest in the possibilities with tailored information and the findings indicate that customised information could be a way to get a position on the market.

The multiple chain stores are controlling how products are exposed in the stores and the possibility to use signs and special stands is decreasing. The multiple chain stores are also demanding more product releases and activities from the A-brand companies in order to accept a brand in the assortment. This means that A-brand companies in a larger extent have to use the packaging as their communication channel and find ways to fulfil the demands from the multiple chain stores. Adding a customised print can be a way to provide an attractive product.

The characteristics of the collected data made it convenient to introduce three levels of customisation: *Customisation for an individual, customisation for a group of individuals with the same characteristics* and *Customisation for a geographical area*.

For the first level, the theory of one-to-one marketing can be applied. However when it's not possible or useful to customise information for each individual it could be advantageous to customise information for different consumer segments and, according to Kotler (2001), focus on customers that more likely will buy the products. Due to differences in logistics it was suitable to introduce two categories of segments: groups

of people with the same characteristics and geographical areas (country, region, store or pharmacy).

Customisation for an individual
According to this investigation, customisation of information for individuals or one-to-one marketing, with packaging as information channel, is a rather unfamiliar concept for the food industry where products are sold in stores. However as the stores today are collecting information about the customers' buying patterns through affinity cards the customers could be divided into different segment and thereafter offered customised information. However, as the customer has to be identified before an offer can be individualised, customised information on food packaging would be more suitable for products delivered to the customer's home then for products sold in stores. Theoretically, one possibility to customise information in a store would be to attach a label on the packaging or to use some kind of "intelligent packaging", with possibilities to change the information on an integrated display. This would most likely be very expensive, but as the technology is developing and prices are decreasing, research within this area becomes very interesting.

According to my findings, 2-3 % of the pharmaceuticals sold in Sweden are customised for small segments or individuals and those pharmaceuticals are packed in standard packaging, without any "product packet insert". This together with the bad statistics concerning the number of deaths due to over- under- and mis-dosings makes it very interesting to complement the physician's prescription with easily digested instructions, customised and printed for the consumer or for an assisting person. Generally more instructions are needed if the consumer is a first time user. Hence potential benefits for the consumer can be achieved through customisation of user instructions. From a marketing department's point of view this opportunity can also be a unique way of establishing a position on the market. It would however be interesting to clearly verify those statements by end-user usability tests and by detail investigate how this could be done.

Customisation for a group of individuals with the same characteristics
The respondents did not have a lot of concrete cases or ideas about customisation for different segments but in general they meant that it would be very interesting to anticipate information for different groups of consumers. Since the stores possess data that could be used to segment buyers, valuable information can be addressed both to the companies representing the A-brand segment and to their own suppliers of packaging (private brand segment).

In order to customise a product for different groups of customers, relevant information about news or a special ingredient can be added. Customised pictures for different customer segments could be very interesting since the customer in a shop is spending more that half of his time looking at pictures (Clement, Sørensen, 2002). Hence this

indicates that customisation of appealing pictures for different customer segments would give a market value.

Within the pharmaceutical industry it is of interest to customise the design of the packaging depending on the patient's demand for a neutral packaging (that is not revealing his/her illness) or for a packaging that is recognizable and associated with the medicine. This indicates that customisation would give the consumer an added value.

Customisation for a geographical area
Among the investigated companies within the food industry it is not very common to make regional versions of packaging, but they are showing an interest for the possibilities. The results indicate that the stores have not had any direct demand for customised products, but they would likely be interested to have versions of products anticipated for their specific shop if the possibility would be offered.

My findings also indicate that customers generally have an interest in knowing the origin of food products. Since a lot of people have confidence in local producers, the name or picture of the local producer on the packaging could give an increased consumer and market value.

The product's impact on the consumer is depending on the positioning in the store and the use of displays and signs (Clement, Sørensen, 2002). A customer only spots 33% of the packaging on the shelves, according to an American study (Clement, Sørensen, 2002). This together with the increasing competition between companies and the demand from the multiple chain stores implies that there is a need for making the packaging more visible to the consumers. Customisation of the packaging according to the conditions for exposure would therefore be interesting. The print on the packaging could theoretically be adapted to specific light conditions and to the general design in the store. As the perception of a colour is dependent on the light source (Johansson, Lundberg, Ryberg, 1998) a daring scenario could be to adapt the print on a packaging to the light source used in a frozen-food display. Customisation of the packaging design, according to the conditions in the store, could accordingly provide a market value but more research is needed to verify this statement.

Within both lines of business my finding indicates that there is a need for information customised for different languages and the ability to read, especially as important text can drown in other information. Within the food industry customisation of the product names for different countries can be necessary as the retailers are demanding saleable names on the products.

Limitations - food industry
According to Feurst (1999) the most important driving force, regarding the possibility to apply a one to one marketing system is the development and distribution of information

technology. Hence one to one marketing is mainly focused on the use of Internet or other addressed channels and is therefore not very convenient for customising packaging in a store, especially as the customer has to be identified before the customisation.

Design is important for effective visual communication (Clement, Sørensen, 2001) whereby copywriters and designers often are involved in the design phase of a packaging. If the volume of packaging is small the cost per piece for this deign phase would be high. Since packaging for the food industry is very price sensitive this is limiting the possibilities to customise information (since smaller volumes is a consequence of customisation).

When the number of different versions of packaging increases, the printed volumes of each version will normally get smaller. This implies that the cost per piece increases, especially when conventional printing technology is used and new printing forms have to be created for each version. My findings also show that more versions of a packaging can increase the risk for stops in the production and make the logistics more complex. Since the products generally (perishable food stuff is one exception) are sent to a central warehouse it could be difficult to reach the correct receiver if the packaging is customised for different stores or customer segments. These consequences of having more versions indicate that customisation of information targeted to segments of customers could be expensive and accordingly extremely expensive if one to one marketing would be applied. Most of the respondents concur that the Swedish market is too small for making regional versions of products.

Within the food industry, no special ethical aspects can be highlighted from the collected data besides that it is important to provide true information on the packaging. Regulations are setting rules for how information on a packaging can be designed, which could make the designer's task more difficult or time consuming. Otherwise the legal aspects are not that critical within the food industry.

Limitations - pharmaceutical industry
According to my findings it is difficult for the pharmaceutical companies to produce small volumes because of logistics and production related issues. As consumer documents and production documents need to be updated every time a new product is to be produced, small volumes would be expensive. To get large-scale advantages, most of the companies are ordering lots of no less than 5000 pieces of packaging, which can be seen as an economical factor setting a limit for the minimum size of different segments of customers.

The same logistical problems (as in the food industry) about reaching the right customers will also arise for the pharmaceutical companies if packaging would be customised. However this seems to be valid only for large companies with large

production sites, since there exist production sites where individualised pharmaceuticals are produced. Further research on workflow analysis of these "small scale" production units would be very interesting as the benefits of customising information for the consumers within this line of business is very high. However there is a need for further investigations of how the end-users understand the information given by the physicians and how complementary written information is understood. As the available space on packaging for pharmaceuticals is small, most of the information has to be attached in some other way. Hence both logistical and economical issues are critical factors for customisation.

As the companies, due to logistics and economical reasons, find it hard to customise products, it would be interesting to customise the information later in the value chain at the pharmacies. However, according to the law, the producers are responsible for their products and the attached information, which means that the pharmacies are not allowed to insert any additional information customised for a special need. This implies that the end user can get a "product packet insert" with a long list of indigestible information, but only a few relevant sentences. Another limiting factor for customising information is the time-consuming approval process at the Medical Product Agency, especially as every single change of the written information has to be approved. Hence legal issues are limiting the possibilities to customise information at the pharmacies, which means that it is only up to the physician to customise the prescriptions.

Personal integrity has to be considered carefully before a product is customised and it is important to consider that significant information can become less visible if pictures are used for marketing (which is allowed in some countries). Hence ethical issues can also be a critical factor that has to be considered before information is customised.

My findings show that the price on packaging is very sensitive but within the pharmaceutical industry the products are rather expensive. This implies that it is generally easier to motivate a higher cost due to customisation within the pharmaceutical industry than within the food industry.

6. Discussion

As shown by the analysis this study highlights potential benefits and limitations using customised information on packaging. However more research is needed in order to weigh the potential benefit against the limitations and costs in order to find realistic business cases. It is important to emphasise that the printed information on the packaging is only one media for affecting a customer. The smell, the sound and the touch of the product as well as other channels of information are also stimulating the customer (Clement, Sorensen, 2002).

In digital printing the trend is toward better print quality and lower cost per printed copy. This together with the possibilities to individualise every printed product makes it

very interesting to investigate how the production and logistics system should be designed in order to create relevant business opportunities. Dante, Karles and Basak (2000) mean that it is important to realise that some of the information is fixed among all packages whereby only some parts are interesting to customise. If hybrid printing (conventional printing technology combined with digital printing) is used, large-scale advantages can be combined with the possibility to individualise the additional parts that are not fixed. The potential value of a printed packaging is in a high degree dependent on the print quality, which also highlights, especially if a more complex system for hybrid printing is used, the importance to focus on activities such as test printing.

For both lines of business the results concerning logistics and production related issues are most likely not depending on the location of the production site, whereby those results should be representative for other countries as well. In countries where regulations and sales channels are comparable with the Swedish conditions the general results regarding the pharmaceutical industry should be representative. Regarding other lines of business the health food industry have similarities with the pharmaceutical industry, even if the regulations for the latter are stricter.

The analysis shows that the driving forces for using customised information on packaging (including the "product packet insert") in general are the increasing competition between companies, the higher demands from the retailers and the possibilities to give the customer an added value. Hence the driving forces can be summarised as the *potential possibilities for an increase in market value and consumer value*. The use of customised information on packaging can be an interesting way to get a position on the market. Figure 1 is showing in more detail how consumer and market value could be achieved. As shown in the figure a consumer value also corresponds to a market value while a market value not necessarily corresponds to a consumer value.

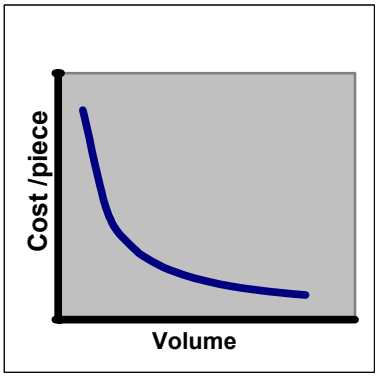
Customisation for individuals
Pharmaceutical*:* instructions aimed at patients and assistants → **consumer & market value**

Customisation for groups of individual with the same characteristics:
Food*:* differentiation of information / pictures on packaging → **market value**
Pharmaceutical*:* differentiation according to the patient's sensitivity to reveal his/her need for pharmaceuticals → **consumer value, market value**

Customisation for a geographical area:
Food: anticipation of languages, tailoring according to the ability to read and according to the origin of local products → **consumer value, market value**
Saleable product names → **market value**
Conditions in the store → **market value**
Pharmaceutical*:* language → **consumer value, market value**
Name of retailer → **market value**

Figure 1. Driving forces for using customised information on packaging

However, according to the analysis, economical, logistical, ethical, and legal factors are limiting the potential possibilities (see figure 2 and 3).



When the printed volumes are getting smaller, due to customisation, the production costs/piece, the design costs/piece and the costs for logistics/ piece are increasing. The use of digital printing could however lower the production costs since there is no start up costs for a print form. It could also be possible to change the costs for the logistics if the customisation task is performed by a digital print at the local market. The cost for design is however not affected by the use of digital printing, whereby that limitation remains even if digital printing is used.

- The logistics gets more complex
  - when the number of versions increases
  - as products are passing through a central warehouse (Difficulties to reach the right customer)
  - especially for the large production sites of pharmaceuticals (production documentation)
- In order to gain large-scale advantages lots > 5000 pieces are ordered (pharmacutical industry)
- Packaging for food is very price sensitive
- One to one marketing is still a challenge for packaging in stores
- The processing at the authorities for approval of pharmaceuticals is long (every single change has to be approved).
- The producer's responsibility for his product is limiting the possibilities for customisation of information later in the value chain, at the pharmacies.
- Personal integrity has to be considered carefully (pharmaceutical industry)

Figure 3. Limiting factors for using customised information on packaging

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Paper II

Customised Information on Packaging – Production Flow and Logistics for Hybrid Printing Solutions

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Abstract

In order to efficiently produce packaging with customised information the design of the system for logistics and production flow is critical. With a pre-set base layout for a packaging there are several print technologies that can be used depending on the required print quality and cost limitations. Using conventional technologies, long series give a low cost for a single packaging, due to cheap reproduction once the printing forme is produced. If customised messages are to be added and printed on the packaging, the preferred technology is digital printing.

In an ongoing research project, the purpose is to investigate the possibilities of obtaining both high quality and economically viable customisation using hybrid solutions, where conventional flexography printing technology is combined with digital printing. The purpose is to find out where in the value chain a digital printing task can be inserted and what the associated benefits and obstacles are. Three possible scenarios with different ways of applying customisation are described.

1. Customised information added on the packaging directly after the conventional printing.
2. Customised information added on the packaging when it is filled with content
3. Customised information added on the packaging at the wholesale dealers /retailers.

There are however many parameters to consider in order to have a complete picture of the costs and benefits for the whole value chain. In this paper, two of the parameters that today restrain the trend toward shorter product series are investigated: changeover costs and cliché costs at a flexography printer. This gives necessary knowledge for the continuous research towards a complete evaluation of the different scenarios. The study is based on quantitative research through case studies at companies including a producer of packaging (printer) and a filler (producer).

By using a hybrid printing solution one basic design printed by conventional technology can be customised into several variants of packaging using digital printing. The results show that the differences in cost for the two parameters are considerable for small

volumes. The analysis indicates that the second scenario is advantageous in some aspects but more research is needed to map out the whole value chain in order to get a complete comprehension of the cost and added value from a hybrid printing solution.

1. Introduction

A general trend today is that the quality of similar products from different brands is becoming more and more uniform (Olsmats, 2001). This means that a strong brand and the packaging design are of paramount importance. One way to make the product competitive and adapted to market forces is to tailor the information on the packaging specifically for customers or retailers. This is in line with the new trend, which, according to Loutfy (2002), is to sell products prior to production, as opposed to the traditional way where products are first produced and then marketed. According to Olsmats (2001) packaging can function as a very cost effective marketing tool.

Kotler (2001) defines two extreme methods of marketing: massmarketing and micromarketing (complete segmentation). Between these two extremes are segment marketing and niche marketing. To better reach the customers, companies can divide a large heterogeneous market (where massmarketing can be applied) into smaller segments and thereby offer products adapted for each segment. Segments normally consist of large identifiable groups based on for example geographic or demographic variables. A subgroup within a segment is called a niche and the idea behind niche marketing is to more precisely satisfy the customers' needs. The most extreme method of marketing is micromarketing, where products and marketing are tailored to fit specific individuals (Kotler, 2001).

In order to hold small-scale campaigns in different countries and different markets, there is a considerable need for personalized packaging (Sarelin, 2001). An investigation focused on the food and pharmaceutical industry, within the business to consumer sector, showed that the driving force behind the use of customised information on packaging is the possibility to increase a product's consumer and market value (Viström, 2003). This possibility could be of great importance in order to win a position on the market, especially since the competition between companies continues to increase (Viström, 2003).

The business-to-business sector is also very interesting and challenging for customised packaging printing. Business markets are similar to consumer markets as the same people are involved in both types of markets and make purchasing decisions to satisfy different needs. However, a business marketer normally has fewer but larger buyers than the consumer marketer, but the business customer's demand often derives from the demand for consumer goods. Many of the same variables are used to segment both business markets and consumer markets (Kotler, 2001). Fewer buyers in a business-to-business value chain probably implies, however, that the market demand for different

variants will be smaller than in a business-to-consumer value chain. This means that the logistics system, the handling and updating of information in databases, should be less complex and thereby less expensive.

If packaging is to be customised it can for small volumes be economically viable to only use digital printing, since there is no cost for any printing form. However, for larger volumes the biggest perceived limitation is that the cost is too high (Gillboa, 2002). A combination of different printing technologies could however be a way to minimize the increased cost per piece. As some of the information is general to all packaging, there are only certain parts that lend themselves to customisation (Dante, 2000). This means that the major part of the printing can be performed in advance. If a conventional technology is used for this pre-print, large-scale advantages can be achieved when high volumes are produced. If digital print is added afterwards, we get a hybrid printing solution that has both the potential to achieve large-scale advantages and the possibility to customise the information on each packaging. Since the cost of ink for ink jet and electro photography (two main digital printing technologies) accounts for a high percentage of the total cost of ownership (Kipphan, 2001), the total cost of pre-printing with conventional technology and thereafter adding smaller customised prints could be much lower compared to printing the whole packaging series in a digital press.

One interesting hybrid solution is flexography combined with digital printing. Flexography can be used for a wide variety of materials (paper, cardboard, plastics, metal), which means that this technology is well suited for the packaging industry (Johansson, Lundberg, Nyberg, 2001). Flexography is predicted to remain one of the major printing technologies and is especially suitable if flexible materials such as plastic film are used as substrates (Kipphan, 2001). The trend indicating that plastics will be used to an increasing extent within the packaging industry (Riley, 2003) is yet another argument for the use of flexography.

A digital printing task can be performed at different parts of the value chain. One option is to let the addition of digital print follow directly after conventional print. However by adding the digital print further down the value chain, advantages such as flexibility and the postponement of information binding can be achieved. Depending on the point in the value chain where the digital print is inserted, the logistics and the production workflow of the whole system may be affected in different ways. These issues are analysed in an ongoing research project, where the purpose is to investigate the opportunities offered by a hybrid printing solution and to evaluate the optimal point in a value chain for the customisation task.

2. Research objectives and methods

In this paper, three possible scenarios in which the digital print is inserted at different positions in the value chain are described, which will give a comprehensive

understanding of the research. However to evaluate the value and costs for hybrid printing solutions and to find the optimal location for the customisation task (digital printing), many parameters have to be investigated. This paper focuses on two particular parameters (changeover and printing forme costs for conventional printing) that today are limiting the development for shorter series. The purpose of this study is therefore to:

investigate if and how changeover costs and printing forme costs can be reduced when using a hybrid printing solution instead of conventional printing

Both the business-to-business segment and the business-to-consumer segment are interesting but in this paper, I have chosen to focus on the business-to-business aspect. There are several actors in a business-to-business value chain, who could gain advantages from tailored packaging. Middlemen could improve their marketing and make short run campaigns on the fly. There are also possibilities to increase the customer value of the product.

Within the business-to-business sector I have chosen to focus on the production of packaged paper reams in the paper industry. Paper producers are increasingly competing with products of uniform quality, which makes other factors such as logistics and branding decisive for whether the customers will make a purchase or not. Within this segment it is possible to identify specific niches. It could for example be interesting to adapt the information on the packaging for different geographical areas and specific printer equipment or offer to print customers' logos on the packaging. Many of the paper producers' customers are today asking for their own packaging design, but for small customers this is today considered too expensive.

Hence, this study will use the production of wrapping paper for reams in the paper industry as a case in studying the benefits and limitations of hybrid printing for packaging. The study is mainly based on primary sources (respondents at the selected companies). In addition, secondary sources (books, articles, Internet) are used to obtain information about related research and to collect interesting theories for use in the analysis.

Quantitative research using case studies performed at companies in the value chain, including the packaging producer (printer) and the filler (producer), was carried out during 2003. The collected data are based on interviews with respondents at the packaging producer and the filler. The price figures quoted are indicative, collected in 2003 and converted to euros. Observations of the production workflow also took place and wholesale dealers have been interviewed in order to have a comprehensive over-view of the value chain.

Respondents:
Flexography printer: CEO, production manager, 2 operators
Paper producer: stock control supervisor, 2 production planning assistants, group product manager home & office, packaging line responsible, sales manager office paper
Wholesale paper dealer: division manager office paper
Wholesale office equipment dealer: CEO
Printer manufacturer: controller/purchasing manager

3. Scenarios for digital print

Three scenarios are presented here, illustrating the different points in the value chain where digital print can be added. Based on these scenarios it is possible to evaluate the opportunities and consequences of having a digital printing task placed with the different actors in the value chain: the packaging producer, the product producer (the filler) and the wholesale dealer/retailer. Other possible scenarios where new middlemen are introduced could also be defined but here, the number of scenarios has been limited to three, S1-S3.

S1: Customised information added to the packaging, directly following conventional printing at the *packaging producer (c1)*.

S2: Customised information added to the packaging when it is filled by the *producer (the filler, c2)*

S3: Customised information added to the packaging at the *retailers* (*c3)* on the local market.

According to Dante (2001), the most flexible platform for product customisation is integration of the printing and packaging operations. This corresponds to the second scenario and means that the printing could be changed during an ongoing process, which is the prerequisite for an on demand printing system. However, such a system carries a risk of interruptions in the production line, should printer problems occur. If the printing process is separated from the packaging line there is no risk for interruptions, if printer problem arises (Dante, 2003). There is also a need to verify the output in real time in order to ensure the integrity of the print (Dante, 2001).

Dante also discusses offline-printing close to the final packaging operation as well as integration of a digital printing task within the flexography press (corresponds to scenario 1). In my approach, I have also chosen to consider the possibilities of having a digital printing task at the wholesale dealers (scenario 3) since these actors are closest to the customers at the end of the value chain.

S1: Customised information added on the packaging directly after conventional printing
In the first scenario a digital printing device is installed directly after the conventional press. This means that the speed of the conventional press and the digital printing device

have to be synchronised, if the digital printing is performed in-line. After the printing is made the packaging is transported to the filler, who will use them to pack his products. Flexo presses can at least reach speeds up to 300 m /min but many times they run at a speed of around 150 m /min. Several production steps and transports before the customised product reaches the customer would likely imply a higher risk for delays.

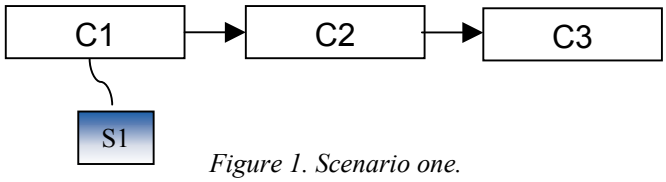

Figure 1. Scenario one.

S2: Customised information added on the packaging when it is filled with content
In the second scenario the packaging producer is producing pre-printed packaging that are delivered to the product producer (the filler). For S2 the digital print can be added in-line before the packaging is filled or after the product has been packed. The latter alternative will most likely be more complicated since a packaging filled with content is 3-dimensional. Cubic packaging has six sides for printing, as opposed to a flat packaging substrate that in most cases only has one side that is of interest for printing. After the products are packed they are delivered to the wholesale dealers /retailers. As for scenario 1 the speed of the digital printing unit has to be synchronised with the speed of the packaging line, unless customisation is made off-line in another press. The packaging lines is normally much slower than flexography presses, which means that the demand on the digital printing device is not as high. At lower speed it would also likely be easier to assure the integrity of the print and depending on the chosen equipment the print quality would likely be better.

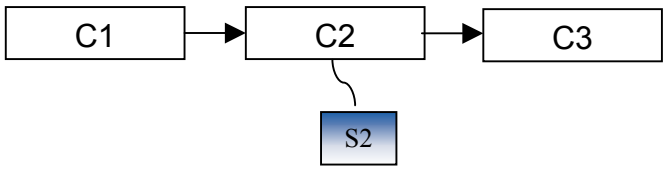

Figure 2. Scenario two.

S3: Customised information added on the packaging at the retailer on the local market
In the third scenario the packaging producer is producing pre-printed packaging, which thereafter are delivered to the filler, who fills the packaging with content. The packaging are then sent to the retailer. At C3 information is added on the packaging by digital printing before the products are sent to the customers.

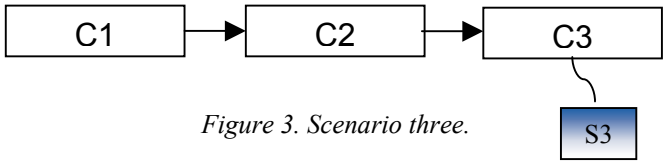

Figure 3. Scenario three.

Adding the digital print at the wholesale dealer or retailer is maybe the most flexible way of customising a product. It could however be very expensive to print on packaging that is stored in a warehouse or at a retailer. There would likely be a lot of manual handling and if some kind of system for feeding packaging is to be installed to print inline it could be very expensive. For a high value product, with a good margin, it could be motivated to make a customised print at the wholesaler, but for a high volume product (with a low sales price) the cost for making the print has to be very low. It would accordingly be hard to motivate customisation of high volume products at (c3), especially since the products most likely also have to be unpacked from a delivery container before printing.

If the products are located and customised closer to the customers the deliveries could be more precise and faster. The wholesale dealer would most likely have better contact with the customers than the producer and be rather sure about their needs. One production step and transport to reach the customers instead of several would likely make the delivery faster and minimise the risk for delays. This will however depend on the printing equipment used for the customisation and the present workload at the wholesale dealer. It would likely take more manual handling to customise the products at a wholesale dealer or a retailer, whereby the capacity to handle a large number of customers would be limited. This could however be regulated by focusing the customisation task towards the most valuable customers, whereby micro marketing could be applied.

Technical aspects
According to Ashley (2003), ink jet technology is rather suitable for printing directly onto packaging materials. One advantage is that the imprinting unit does not enter into contact with the substrate, which might not be completely dry following conventional printing (Kipphan, 2001). As ink jet printing is a non-impact technology, the thickness of the substrate is irrelevant (Moncarey, 2003), which also means that it is possible to print on packaging after the product has been packed, which is a prerequisite for scenario 3.

The speed of electrophotography (around 60 m/min) is generally lower than ink-jet (120 m/min), which also has the possibility of operating at different speeds (Kipphan, 2001:2). Since speed is a very important factor in inline printing, and electro photography has a more limited variety of printable substrates, ink jet would seem to be the most interesting alternative.

One major problem in setting up a hybrid printing system is that the top speed of the different printing units varies a great deal. For single colour printing, the fastest non-impact printing technology reaches speeds of between 0.3 –5 m/s. (electro photography, magnetografi, ink jet), while multi colour printing normally reaches speeds of between

0.1 and 0.5 m/s (electro photography, ink-jet). These differences in speed can make it impractical to build an inline hybrid printing system (Kipphan, 2001). A prototype inline variable data imprinting unit, based on drop on demand technology was developed by Heidelberger Druckmaschinen AG. This unit can print variable data in full colour at a speed of 1.6 m/s, providing quality prints in 600 dpi (Zhou, 2001). There are also other print heads (for example from Scitex) that can manage to print 300 dpi at speeds of over 150 m/ min. These examples and the continuous development of ink jet technology gives a clear hint that print heads would be fast enough to set inline with a flexopress running at speeds over 150 m/min or a packaging line running at 20 m /min, which is a requirement for scenario 2 and 3.

4. Theoretical framework

In this section some theories about logistics and differences in requirement and aims between production and consumption are introduced.

Logistics is about getting the right product to the correct place at the precise time to a minimum of costs. Through logistics most companies want to increase their profitability or at least retain it. There are three different ways to increase the profit and to improve the profitability, the best method is to work with all three ways (Lumsden, 1998).

- Reduction of costs
- Increasing of the receipts
- Decreasing the capital tied to different types of stock

Business is created through marketing while logistics is needed to complete the sales process. The effectiveness of logistics can be described in terms of delivery service, costs and binding of capital. These terms are dependent on each other whereby all of them have to be considered to know the complete effects when one factor is changed. An improvement of the delivery service may for example give a higher binding of capital.

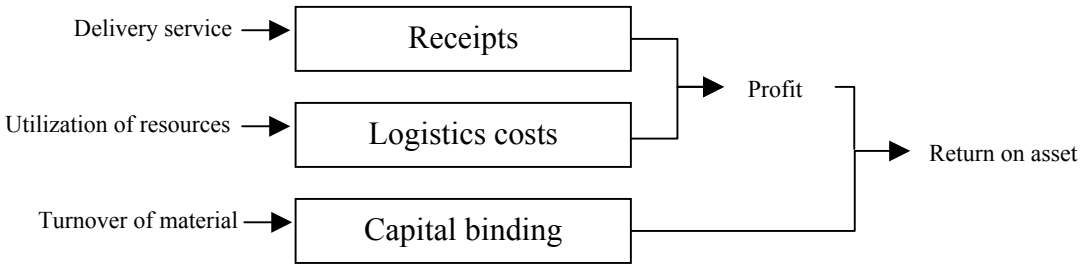

Figure 4. Connection between logistics and return on asset (Lumsden , 1998)

There is a strong connection between marketing and logistics, foremost through the conception of service. Customer service includes everything concerning the relation to

the customer (Lumsden, 1998). However according to the marketing channels literature it is possible to define a number of gaps that illuminate that the producer and the customer have different requirements and aims (Abrahamsson, 1992).

Time gap – The producers are producing continuously in order to achieve large-scale advantages, but the customers are buying the products in discrete intervals.

Geographical gap – The customers are scattered over a large geographical area, while the producers are located on a small number of places.

Quantity gap – The consumers often like to buy small quantities, while the companies are producing large volumes.

Variant gap – The customers have different needs and are demanding many variants, while the producers has a limited numbers of variants of a product.

Communication and information gap – The producers do not always know who and where the potential buyer is to be found. At the same time the desired products are not always accessible for the customers.

Intermediaries are expected to create benefits and bridges between gaps in a more effective way than the selling company (Lambert, 1998). In this paper it will be discussed whether hybrid printing solutions also could be a way to bridge over some of the existing gaps between producers and customers.

Another factor, which is of crucial importance in order to meet the market demand for shorter series and faster updating, is **lead time** which is defined as the time between order and delivery. The lead time includes activities such as receiving of orders, handling of orders, planning, (if necessary) construction, manufacturing and distribution (Lumsden, 1998).

5. The case study value chain

The flow of reams studied applies to a segment where most buyers at the end of the value chain are companies who need office paper in their daily activity. A very small amount is sold to private purchasers (2000 tons per year). The reams are produced and packed at the paper producer (c2) using wrapping paper produced by the flexography printer (c1). They are thereafter shipped to different middlemen (wholesale paper dealers, wholesale office equipment dealers and printer manufacturers) who sell the reams to end-users. In the flow (illustrated in figure 5) data has primarily been collected from c1 and c2.

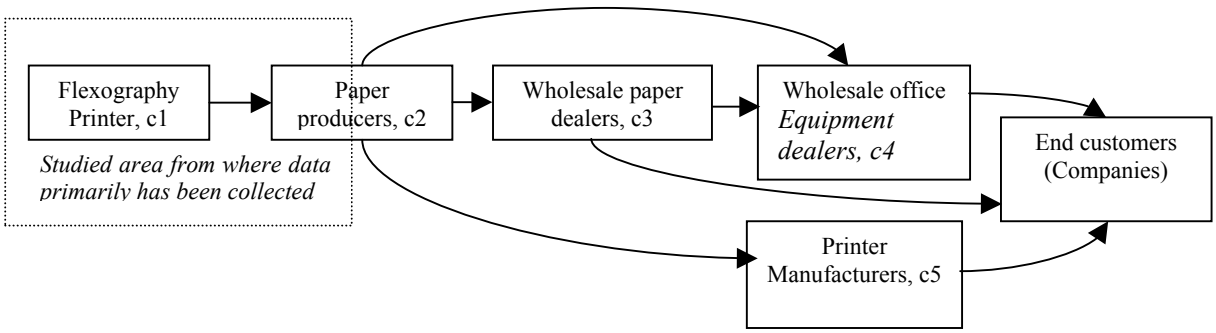

Figure 5. The product flow in the value chain

The Swedish market is consuming 90000 tons of office paper each year and 45000 tons of the total volume of office paper (90000 ton) is sold by (c2). The paper producer has to produce large volumes in order to cover the cost for the production and to make a good profit. In order to achieve this a certain amount of paper is often sold at a lower prize. In order not to damage their own brand the paper producer can sell less expensive products through the private brands of the wholesale dealers. There are about 1000 outlets where one can buy reams (including the wholesale paper dealer, the office equipment retailers and other shops). The end customers are purchasing around:

- 50 % of the volume from the retailers of office equipment
- 30% of the volume from the paper retailers
- 20% of the volume from the printer manufacturers

Wholesale paper dealer (c3)
The role of the wholesale paper dealer is sales, the coordination of deliveries from different manufacturers (thus providing effective logistics) and to offer a wide range of different types of paper. C3 are the largest wholesale paper dealer in Sweden and 95% of their volume is sold to wholesale office equipment dealers and 5% directly to end users. Around 20% of the reams sold by (c3) (white A4, A3) are delivered from stock, while 80% are delivered directly from the paper producer(c2).

Wholesale office equipment dealer (c4)
There are around 500 wholesale office equipment dealers in Sweden but today amalgamations into larger chains are an ongoing trend. When smaller companies become part of larger chains they can place higher demands on the paper manufacturers and wholesale paper dealers. Smaller wholesale office equipment dealers have to buy their paper from the wholesale paper dealers while the chains, due to their size, can buy paper directly from the producer and thereby obtain better prices. Today in Sweden there are 5 large chains of amalgamated office equipment retailers and each of them has

developed their own brand. (c4) is the largest chain in Sweden with an annual turnover of 160 million Euro.

Printer manufacturer (c5)
Company (c5) is one of the largest printer manufacturers in Europe and has several own brands. They buy large quantities of office paper from several paper producers worldwide and can thereby cut prices and at the same time minimise the risk of running out of stock, in the event that one paper producer is unable to meet their demand.

5.1 The flexography printer

The printer studied in this case (c1) uses two flexography presses to make wrapping paper for customers within the food-, paper- and florist industry. One of their main products is wrapping paper for reams that are used by (c2). The substrate used for this product is laminated with polyethylene, which functions as a moisture barrier. The average operating speed is around 150 m/min for both presses.

When (c2) decides to develop a new design for a wrapping paper, an advertising agency produces a design based on c2's ideas. The design is then sent back and forth until approved by (c2). Afterwards a cliché manufacturer makes a proof, which is sent to both (c1) and (c2) within 7 days. After the proof is approved, the clichés are delivered to (c1) 5 days later.

The average lifetime of a cliché (112 * 39 cm) is 70 tons of printed paper (102 g / m^2), which means that it is possible to produce wrapping paper for around 3100000 reams before the cliché is worn out. The lifetime is shorter for fine raster clichés, which are needed to produce good quality pictures. The cost of one cliché is around €800. The average number of changeovers in the course of a year is around 1748. According to the operators, the average changeover time (including cleaning, colour mixing, insertion of new clichés, colour adjustment) is 75 min.

The average sales price is €1.8 /kg, the average cost of paper is €1.09 while the cost of colour is €0,094. This means that the press generates €0.612 for every kilo produced. Since the average paper weight is around 100 g /m2, the average cliché length around 1 m and the average speed 150 m/min, the press generates €9.18 per minute. Hence the changeover time of 75 minutes is equivalent to €688.50. If the changeovers during the course of a year are added together, they correspond to a figure of €1.2 million.

5.2 The paper producer

The filler (c2) studied is one of the largest paper manufacturers in Sweden, producing pulp and thereafter making paper for copiers and printing devices. They produce more than 200,000 tons of paper (A4, A3) annually, which is packed as reams, using wrapping produced by (c1). About 10% of the volume is converted to A3 while 90% is converted to A4. The packaging area consists of three double and one single packaging

line. Four different products can be packed at the same time (it is not possible to have two different variants on the double lines). The speed of each packaging line is around 18 m /min and all lines together can pack 350 reams /min (7 *50 reams/min).

C2 produces and markets five own brands, and 80-85% of the customers for these products are middle-sized companies. Besides their own brands they produce around 20 brands for printer manufacturers and office equipment retailers. There is a total of 84 different variants of wrapping paper. Five are completely blank, which means that there are 79 sets of clichés and a total of 215 clichés when the number of colors for each set is taken into account. Today there are several variants of wrapping paper for each brand, depending on the specifications of the paper (format (A4/A3), perforation, weight). Only a few design details distinguish these wrapping papers from each other, although different weights of paper (80g , 90g 100g etc) require different sizes of the wrapping paper.

Sometimes products for specific orders have to be tagged with particular information. For example some countries insist on the information "Made in Sweden". When the volume is too small to purchase additional clichés for a new design, pre-printed labels are attached to the packaging. 8% of the annual volume sold consists of labelled packaging. There is however a desire to minimise the use of pre-printed labels, since they are problematic. The roll of labels has to be changed every hour (after 6 tons of paper is produced). The price of a pre-printed label is around € 0.011 and two application units (€ 7000 each) are required for each production line.

Today (c2) buys 48 different labels. Eight of these are pre printed to a basic design, which means that the information is printed on them before they are attached to the packaging. Today (c2) has 52 items of different information stored in a database for the customization of labels. There is a total of 165 variants of wrapping paper: 79 designs + 92 labels – 6 designs that need a label attached.

The incoming orders are between 1 and 500 tons, although on some occasions orders as small as 500 kg have been distributed. About 40% of the orders are delivered directly from stock (covers the Scandinavian market) while 60% can only be delivered after the products have been manufactured. The average stock of finished products is around 1800 tons (€1440000), and the average stock of wrapping paper is around 35 tons (€ 58000). If (c2) receives an order at the end of a week, a request for wrapping paper is sent to (c1), who produces the wrapping paper webs and delivers them to (c2) on the following Friday. This means that it will take at least one week before (c1) can start the production of the ordered reams.

When there are not enough products in stock to complete an incoming order or when the stock has to be replenished, an order is sent to (c1), who produces the desired amount of wrapping paper and delivers it to (c2). For the Scandinavian market the goods are

delivered by lorry directly from stock, with a delivery time of around 2-3 days. For other countries products are shipped by sea, which takes around one week, depending on the destination.

C2 often receives enquiries from retailers who are interested in having their own design on the packaging. But since the costs of producing new designs and clichés are high, a customer has to buy at least 1500 tons per year in order to have their own packaging. This has actually led to a decrease in the amount of customised packaging ordered by customers. The number of packaging designs used by (c2) has decreased (world wide) from 160 to 79 since 1995.

6. Results

As described in the introduction, a general trend on the market today is a demand for more variants and faster updating of products. This trend also involves the paper industry. The handling of labels at c2 is one example.

The procedure for creating new designs in the studied value chain indicates that this process can be rather expensive, especially as the cost for designers and copywriters is high (Viström, 2003). Therefore the paper ream producer tries to minimise the number of different packaging designs. Today, the frequency for updating packaging designs is very low (once every 3-4 years). However if the updating frequency and the number of different designs were to increase (in line with the general market trend), the costs involved in updating and/or creating designs or text information could be immense.

If packaging is to be tailored to fit specific regions or other market segments, it is possible to have one basic design that can be customised for each region by the addition of digital print. This implies the possibility of only needing one set of clichés instead of a set of clichés for each region. Table 1 illustrates the difference in cost between one set of clichés and six sets of clichés (a typical situation in the studied case) when the design is updated after the production of 3 100 000 packaging units. As stated in the description of the value chain, the cost per cliché is €800 and for a three-colour design (the average number of colours used at c1) the cost trebles to €2400. This figure corresponds rather well to the average number of colours used by (c2), which is 2.72 (215 clichés divided by 79 designs). However, if the demand for more colours on packaging were to increase (c1 had to buy a new press to produce 7 colours jobs), the average numbers of clichés will increase and thereby also the cost. The cliché cost per ream (3 colours) is around €0.00077 if the cliché wears out after 3100 000 packaging units, which is the figure used in the example. By using hybrid printing it will be possible to wear out the clichés even if a basic design is updated more frequently in the future.

Every new order at (c1) means a changeover in the press that according to the calculations above amounts to a cost of around €688.50 (assuming that the press could

have been running during the changeover time). Even if the cliché is used for a large volume of packaging or wears out, new market orders with shorter series will result in a high changeover cost per packaging unit, unless the same cliché is used for different segments during the same printing process (as shown in table 1). If the information in the basic design is less detailed, it is also easier to update the packaging without the need for updating the clichés. Packaging for 20,000 reams corresponds to around 500 kg paper, which are the smallest orders produced today by (c1) and the smallest orders delivered by (c2). According to the example in table 1, a digital printing task for this order size could cost €0.033 per ream in order to break even with the first alternative, where conventional printing is used. However, when the number of variants increases and the series become shorter, the advantages of having one set of clichés for a basic design that can later be adapted by means of digital printing will become greater.

Alt. 1: Separate clichés for each of the 6 regions	**50 kg**	**500 kg**	**2 ton**	**10 ton**
Cost per design & cliché (112*39cm) (€)	800	800	800	800
Number of colours (nb. Of clichés)	3	3	3	3
Total cliché costs(€)	**2400**	**2400**	**2400**	**2400**
Number of packaging before change of design	515768	515768	515768	515768
Cliché cost / packaging (€)	**0.0047**	**0.0047**	**0.0047**	**0.0047**
Changeover costs (€)	688.5	688.5	688.5	688.5
Number of packaging per order	2000	20000	80000	400000
Changeover cost / packaging (€)	**0.34**	**0.034**	**0.0086**	**0.0017**
Total cost / packaging (€)	***0.35***	***0.039***	***0.013***	***0.0064***
Alt. 2: One basic layout for all 6 regions				
Cost per design & cliché (112*39cm) (€)	800	800	800	800
Number of colours	3	3	3	3
Total cliché costs(€)	**2400**	**2400**	**2400**	**2400**
Number of packaging before change of design	3094607	3094607	3094607	3094607
Cliché cost / packaging (€)	**0.00078**	**0.00078**	**0.00078**	**0.00078**
Changeover costs (€)	688.5	688.5	688.5	688.5
Number of packaging per order	2000	20000	80000	400000
Changeover cost / packaging (€)	**0.057**	**0.0057**	**0.0014**	**0.00029**
Total cost / packaging (€)	***0.058***	***0.0065***	***0.0022***	***0.0011***
Alt 1 - Alt 2 (€)	0.29	0.033	0.011	0.0053

Table 1. Comparison of changeover and cliché costs per packaging unit between one and six sets of clichés, for different order sizes.

As stated previously (c2) has 79 sets of different clichés, of which 6 lack specific information, meaning that the wrapping paper thus produced has to be customized in the packaging line by the addition of a label. Since the number of designs has halved since 1995, the number of labels has increased. Hence, labeling is a way of customizing the products inline. It is however, desirable to minimize the use of labels since the label roll has to be changed after 6 tons of paper is produced and according to two people in charge of packaging at two large food producers in Sweden, a label does not look as professional as information printed directly on to the packaging. While some of the

labels are pre-printed, additional information needs to be included before they can be used.

The production of reams could work out less expensive if a hybrid solution is used (as shown in table 1). However, if the cost exceeds the logistical gains the value of adding the digital print must at least compensate for this extra cost. Digital print can for example lead to improved marketing, a higher product value and thereby increased sales. Figure 6 illustrates these two alternatives.

It is difficult to estimate precisely how the total costs within the value chain will be influenced by an implementation of a hybrid printing solution. In addition to the cost involved in the actual digital printing task, there are other costs that may be affected. The cost of administration and the handling of information and goods will more than likely increase when the products are customized and the number of variants increases. A greater variety of packaging also means extra handling costs and ensuring the accuracy of an increased number of products. Hence more detailed observations of the whole value chain are necessary in order to obtain an accurate estimate. Further research on the cost of implementing a hybrid printing solution and how this cost will relate to the added value from customization would thus be interesting.

When it comes to lead time, in order to be in a position to make rapid deliveries directly from stock, there is a need for large inventory. However, if a company stocks an extensive range, the inventory costs could be considerable (Stol, 2003). In order to reduce the inventory, orders can be produced on demand, which means a longer time to market. Since lead time is a very important element of competition, it is preferable to try to keep it as short as possible.

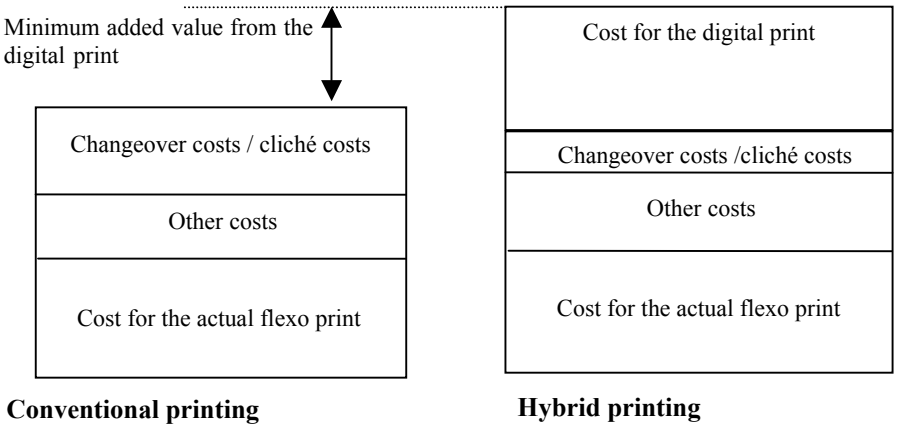

Fig 6. Costs for conventional and hybrid printing solutions.

One possible solution is to try to predict demand and keep the corresponding webs of wrapping paper in stock. This means that the extra week of waiting for wrapping paper

to be delivered from (c1) could be eliminated. However, besides the high costs of keeping a large stock of preprinted paper (necessary to ensure the availability of every single variant) is very difficult to make accurate predictions. However, delayed orders lead to unsatisfied customers. One possible solution would be to reduce the number of different variants of pre-printed packaging to a few basic designs ready for customization, thus minimizing both the stock and the risk of delayed deliveries. In other words, one basic design would be sufficient for several variants. This also implies that (c1) can produce continuously, even if customers purchase different variants at discrete time intervals. Hence, the time gap decreases. However, the customers' demand and the number of basic variants required will determine the size of the stock needed. The corresponding cost has to be compared to the expected gain from a shorter lead time. Among the scenarios described above the second or third would be possible alternatives if this solution were to be applied. For a high volume product such as reams (in the event that every ream has to be customized) the customization should take place inline at the producer's premises, since the cost of retailer customization without a large scale production line will most likely be too high. This leaves us with the second scenario.

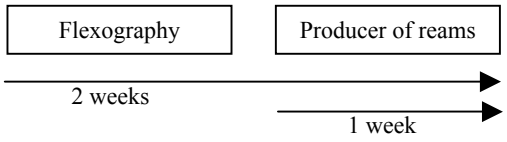

Fig 7. Possibility of reducing lead times if pre-printed webs are kept in stock by the ream producer.

7. Discussion

Hybrid printing solutions could make customisation and shorter series possible at a lower cost, even if many factors have to be considered before a hybrid printing solution can be deemed successful. Conventional printing can be used to gain large-scale advantages while digital print can be added in order to customise the packaging. This means that it would be possible to bridge several of the gaps defined in the frame of reference. In particular, it would be possible to reduce the quantity gap and the variant gap. When the gaps are minimised the production will better meet customer demand.

If a paper producer can offer tailored packaging for medium and small customers due to a successful production flow, it goes without saying that these customers most likely will choose him as their supplier (assuming that the price, logistics and product quality are comparable with those of his competitors).

Only one flexography printer and one paper producer were included in the present study. However, since the paper producer supplies half the Swedish market with reams, it is no doubt the most representative company in Sweden. This study should be of interest to value chains which include a flexography printer making wrapping paper for

producers that have a packaging line, although the exact figures and the demand for customization will however most likely vary according to the line of business.

As mentioned previously, more research is needed to investigate the cost of implementing a hybrid printing solution and whether the cost is justified by the added value from customization. According to a large print head manufacturer, every new installation of in line ink jet printing involves a great deal of specific testing. Many parameters have a bearing on the print quality (e.g. speed, substrate, type of print, ink jet technology, type of ink). This makes it more difficult to provide a general answer to the question of how much a hybrid printing solution will cost.

8. Conclusions

The study shows that, by using a hybrid printing solution combining flexography and digital printing, it is possible reduce or at least maintain existing changeover- and cliché costs should future market trends favour shorter series and more frequent updating. This can be achieved by decreasing the number of basic designs on packaging and have them customised instead, for example on the producer's packaging line, before delivery to the customer. This could also result in a reduction in lead-time. However, these decreased costs, the additional customisation costs and the added value from providing customised products have to be evaluated in relation to each other in order to ascertain whether or not a hybrid solution for providing customised information on packaging is economically viable.

9. Acknowledgements

The author would like to thank the studied companies for their kindness, courtesy and co-operation, in particular my supervisor at KTH and colleagues at Framkom for their valuable comments and for proofreading the manuscript.

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Paper III

Inkjet Inline Printing – Identification and Analysis of Critical Production Related Parameters

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Keywords: Productivity, high speed inkjet, packaging , digital printing

Abstract

Inline printing on packaging is becoming an important factor due to market demands for shorter product series and flexibility in production. Print speed, set-up time and print quality are examples of important parameters to consider assuring high productivity in the printing process. This paper will identify and analyze production-related factors that characterize productivity in inkjet printing through studies on high-speed inkjet printing. Typical production lines are studied in parallel to characterize demands from the packing machines as well as other related factors. This paper discusses whether the characteristics of the identified factors for inkjet printing work in conjunction with the current production lines. The results indicate that inkjet is an interesting alternative for inline printing, but that the reliability of the inkjet unit is of crucial importance.

Background

Inline printing of barcodes, best-before dates and batch numbers on packaging has been available for several years while more sophisticated printing of text information, logos and pictures in four colors is just now starting to catch producers' interests. Industries that today order and use packaging solely produced by conventional printing technologies are getting more interested in digital printing solutions. Driving factors are the potential to gain marketing and logistical advantages. According to Morgavi (2003), the driving force comes from customers that are demanding adapted products to an increasing extent.

Many product variants, different languages and legislation make it a complex task to satisfy all packaging requirements. However integrating digital printing in existing production workflows can realize benefits and savings (Birkenshaw, 2003). Stock reduction, shortening of lead time, change-over time reduction and higher flexibility are possible to obtain through the introduction of a hybrid printing solution where a digital print is made on pre-printed packaging (Viström, 2003b).

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An inline printing solution can also improve marketing. Information on packaging could, for example, on the fly be tailored to fit specific consumers or customer segments. It has been shown within the food and pharmaceutical industries that customized information on packaging has the potential to give products higher market value and increased customer satisfaction (Viström, 2003a). According to a study of companies within the corrugated packaging market, 70% desired better methods to handle different languages, designs and stock keeping; 83% desired a better correlation between marketing activities and the packaging (Fredriksen, 2002).

Digital printing gives the unique opportunity to customize information on every printed copy, which means that the technology is applicable for on-demand production (Birkenshaw, 2003). Inkjet which is considered as a viable digital printing technology for customization of information inline, has the advantage to keep the printing unit from coming into contact with the substrate. Due to this non-impact process, an inkjet printer head can print on any substrate regardless of thickness (Moncarey, 2003), which also means that it is possible to print on packaging material even after folding it into a three-dimensional package. Smith (2003) further strengthens that inkjet technology is very promising for future packaging applications because it can be relatively fast and print on a wide variety of substrates with different ink types. Another big advantage of inkjet printing is the high consistency of color density compared with xerography (Daming, 2003). Since specific colors are often closely associated with a brand product (Holger, 2002), color reproduction is of major importance.

To profit from a digital printing solution integrated into an existing workflow, it must work satisfactorily in industrial environments and be reliable in critical situations, not creating a bottleneck. In addition, the vendor should be able to guarantee 24-hour service if the equipment should fail (Veresh, 2003). Hence it is of crucial importance to uphold a high productivity, which can be defined as "the ratio of output of a production process to the input" (Evans, 1993). Even if the system performs well, it is of crucial importance that costs are not too high compared with potential gains (Veresh, 2003). The cost per printed unit is still high compared with conventional printing for large quantities but by printing "On demand" savings of administration, distribution, waste, warehousing and production costs can be realized, offsetting the higher production costs (Birkenshaw, 2003).

It is evident that digital printing integrated inline has the potential to create both savings and benefits, but there are challenges to overcome in order to achieve satisfactory productivity. The purpose of this paper is to:

Identify productivity related factors in high speed inkjet printing and investigate whether these factors work well in conjunction with current production lines.

This paper will focus on the opportunities of inline printing solutions even though offline printing might be advantageous in some situations. Aspects on investments and variable costs for printing systems are not included in the study; neither are aspects on the information workflow necessary for variable data printing.

Characteristics of high speed inkjet printing

High-speed inkjet applications are characterized by having fixed "single pass" printer heads that cover the whole print width (Stowe, 2003). Single pass systems have a separate printing unit for each color (Kipphan, 2002), which means that the substrate only has to pass under the printer heads once.

The achieved print quality is dependent upon whether the ink and printer head are adapted to work together. Variations in drop velocity, frequency and volume, as well as air bubbles and blocked nozzles can give variation in the print quality in single pass systems (Smith, 2003). If a printer head meets with nozzle blocking, this means that one or more nozzles are obstructed and not able to jet the ink. There is also a risk for side shooters, which means that one or more jets are pointing in the wrong direction. A way to increase print quality is to use "gray scale" printer heads building-up every single pixel by one or several droplets. This technology gives a higher perceived resolution and can reduce the sensitivity to some of the variations mentioned above (Smith, 2003).

Inkjet technology can be divided into "continuous" and "drop on demand." A constant flow of droplets is generated using continuous inkjet, but only part of the droplet flow is transferred to the substrate. Droplets not used for printing are deflected by an electrical field and transferred back into the system. Using "drop on demand," droplets are produced exclusively when they are needed for the print (Kipphan, 2001). Continuous inkjet is still the dominating technology in packaging and direct mail markets, but recent advancements in the Piezo drop on demand technology makes the latter technology also very interesting for future applications (Schwartz, 2002).

In Pira's report "The Future of Digital Color Printing," high speed continuous inkjet presses are described as the fastest color printing systems, illustrating the future potential of inkjet printing. These exist systems that are built on water-based continuous inkjet technology and can print variable information at a maximum 300x600 dpi at 150m/min using four colors. (Smith, 2003). Printer heads can be purchased separately in order to develop specific printing systems in-house.

The "drop on demand" high-speed inkjet segment is also described as very interesting. There exist printer heads using "gray scale" Piezo drop on demand technology that allows eight gray levels for each pixel (300 dpi). The output is claimed to have a visual resolution of more than 900 dpi and can reach a printing speed of 24m/min. UV-curing pigmented inks are typically used (Smith, 2003). When it is sufficient to have a lower

resolution there exist other drop on demand printer heads that are somewhat faster (39 m /min) providing 200-300 dpi.

Piezo drop on demand inkjet printer heads are considerably less expensive than continuous inkjet printer heads, which reach much faster print speeds (Wilson, 2003). However, droplet frequencies of 100kHz are claimed to have been achieved on the laboratory scale for drop on demand technology. This drop frequency would correspond to a linear speed of 63m/min at 600 dpi (Smith, 2003).

Only two types of ink are typically suitable for continuous inkjet (water or solvent-based) (Schwartz, 2002), while there are several options for the drop on demand technology. One example is oil-based pigmentary inks, which compared to water based inks gives a rapid drying time, a high light fastness and less cockle on the substrate, implying that a high print speed could be achieved (Schofield, 1999). Another example is UV-curing ink that has an excellent reliability in single pass web printing systems (Niegel, 2003) and is used successfully in other conventional print technologies. Other advantages are high opacity, fast drying, good preservation of ink consistency, no drying of ink in printer heads and good scratch hardiness (Stowe, 2003). A major challenge when UV-curing inks are used, however, is to assure that undesirable substances do not migrate through the packaging walls causing food contamination (Niegel, 2003). The option to choose between different ink types is advantageous since there exist many different packaging substrates requiring different ink types to get a good ink adhesion. This paper is therefore focused on the drop on demand technology even though continuous inkjet also is of major interest.

General description of packaging lines

Packaging materials can be divided into flexible, semi-rigid and rigid. A flexible packaging material may consist of paper, plastic film, aluminum foil or combinations of these materials and are fed from a reel and formed directly in the production process. Carton packaging and cardboard packaging that are delivered flat belong to semi-rigid packaging, while glass packaging, tins, etc., are classified as rigid packaging (Andersson, 1997). This paper focuses on flexible and semi-rigid packaging since they seem more suitable for printing directly onto the package.

Three basic functions for packaging technology are forming, filling and sealing. When forming flexible and semi-rigid packaging, is it crucial to attain sufficient stability to manage subsequent filling and handling. When the carton packaging (semi-rigid) is filled and sealed, it obtains the stability needed for distribution and consumption (Andersson, 1997). There exist several ways to pack products and each packaging line normally has it's own specific solution. A rule of thumb, however, is to always have more capacity in a following machine (Begéli, 2004). Some machines use pre-folded packaging while other machines form, fill and seal the packaging. Besides these basic

processes, there exist complementary functions, such as transportation, sterilization, marking, labeling and check weighing (Andersson, 1997).

Among carton machines, there exist systems that fill packaging from above (top-load) and from the side (side-load). Top-load machines are used for free-flowing products like rice, powder, frozen fish, vegetables, cereals, etc. If additional objects are to be added into the packaging (instructions, stickers, etc.), top-load machines are advantageous. Side-loaded machines are characterized as smaller and less complex than top-load machines. Blister packaging containing tablets are typically packed in cardboard boxed by side load machines. Another type of system inserts products into sleeves. Cartons are delivered as pre-glued or flat blanks. The latter is folded and glued inline while the former is erected inline by pressing two opposite corners. Pre-glued cartons require less complex packaging machines, but when the packaging is to be filled as a multi-pack box, it might be easier to use flat blanks since they are folded after the product has been put in position (Begéli, 2004).

Methodology

Two companies that use high-speed inkjet printing systems were the objects for case studies carried out during 2003-2004. In parallel, three companies within the food and pharmaceutical industry were studied to gain knowledge about the characteristics of typical production lines. Through the first case studies aimed at collecting users' experiences from inkjet equipment, productivity related factors in high-speed inkjet printing were identified. In the next step, these identified factors were compared with collected data from the studied production lines to conclude whether this printing technology works well in conjunction with the production lines or not.

Personnel responsible for or deeply involved with the build-up/installation of the printing system were the respondents in the first category of companies. Production managers were interviewed at the other companies.

Case study companies

User 1, U1. U1 is a printer working mainly in the labeling industry and was chosen for case study because they are the first company in the world to install a web-fed printing system consisting of the Dotrix SPICE inkjet engine mounted on a Mark Andy 2200 flexo press. (Currently SPICE is the only drop on demand single pass system (Smith, 2003).) More details about the configuration of the SPICE printer can be found in (Daming, 2003). This press makes it possible to produce short run color prints at a high speed assuring that the color density is stable. Customers' demand on print quality varies depending on their line of business. For some customers, a few misprints because of blocked nozzles are acceptable while others want impeccable print. Print quality is particularly important within the pharmaceutical industry since a misprint on dosage instructions can have serious consequences.

User2, U2. U2 produces industrial products sold primarily to business customers. U2 was chosen for the case study because it was one of the first companies in the world to install a four-color sheet-fed inline printing system in one of its packaging lines. Full print color is obtained by printing the four basis colors (cyan, magenta, yellow and black) over each other. The company's focus in August 2003 when they installed the equipment was to stabilize the printing process. It has now switched its focus to an improvement in print quality. An important advantage of having a full color printer inline is the flexibility gained when producing new commercial products. The company also no longer needs to keep stock of the tape containing commercial information that was found glued on the packaging. Furthermore, lead time has been reduced, which implies that time-to-market for new designs is shortened. This system (of which the printer is a part) makes it possible to produce gift boxes and special campaign designs on very short notice, which gives a higher flexibility and additional advantages, especially when considering that 10% of the products are co-branded.

As with all the other companies, print quality is important, but because U2 sells its products to business customers, print quality is not as important as if they were sold directly to consumers. A few misprints because of nozzle blockings are acceptable for this customer segment. As of today, this printing system does not have print quality sufficient enough to print on consumer packaging; however, steps are being taken to improve the quality of the prints to a level that is also acceptable for the consumer segment.

Case study companies (packaging lines)
Among the different packaging applications, food packaging in particular is attracting much interest. Short run printing, inventory reduction and customization are the main drivers for this activity (Nigel, 2003). The food and pharmaceutical industries are described as interesting to customise information on the packaging (Vistrom, 2003a). Two companies within the food industry and one within the pharmaceutical industry were chosen as case studies.

Producer1, P1. P1 is a typical company within the food industry that produces pasta, cereals and porridge oats. This study, however, is primarily based on data obtained from pasta production for the consumer segment. Top-load machines are used to pack 24 variants of pasta into carton-board packaging. Web-fed machines pack seven different types of spaghetti in plastic film (flexible packaging).

Producer 2, P2. P2 is one of the largest pharmaceutical companies in Sweden and sells pharmaceuticals worldwide. They believe it would be interesting to minimize the number of pre-printed packaging types using alternative printing methods. There are currently 240 packaging variants (30 markets times eight versions) for one of their typical products. Demands on print quality are extremely high since a misprint on

dosage instruction could have serious consequences for a patient. Authorities in several countries would have to approve the use of a new print technology on substrates that come into direct contact with the pharmaceuticals. This approval could take several years. Therefore, it is important that the new technology is stable before it is introduced to the market. Regulations are less strict when printing on substrates that do not come into direct contact with the product.

Producer 3, P3. P3 produces all types of dairy products and 100,000 tons of milk in used in the production process each year, 45% of which is refined for regular milk. Milk cartons have information panels that frequently change. At the time of this study, the production plans for the next seven weeks included ten different panels. Hence, an inline printer system could provide more flexibility to update this information.

Results (users of printer systems)

Equipment /production data

U1. The printer system at U1 contains a hybrid solution that can both print specific PMS colors using flexo and variable data in four colors at 300 dpi (8 gray levels) by the SPICE inkjet engine. The print speed (maximum 24m/min) is variable and can be adjusted during production. However, if thick ink layers are applied, a speed of 20m/min has proven to give the best print quality. The distance between the printer head and the substrate shall be within the interval of 0.7 – 0.9 mm to obtain good print quality. UV curing ink is used and it dries immediately after it has passed under a set of UV lamps. In order to get a better print quality and ink adhesion a special coating is applied before the printing.

The printing system performs best at indoor temperatures (20°C), which is the prevailing condition at U1. Since the press is very precisely calibrated, there is a risk for problems if the press runs in a cold environment (8°C). Metal parts expand when the working temperature increases to 40-50°C and contracts when the press is turned off, whereby affecting calibration. It is also important to avoid condensation, which can appear due to temperature changes. There are otherwise no special humidity requirements to use the printing equipment.

U2 U2 uses oil-based printer heads (XJ126) to print on filled packaging (sleeves). The printer heads are based on drop on demand technology from Xaar, providing a resolution of 180 dpi. The same type of white corrugated board cut as flat blanks is used for all sleeves, but the quality of the purchased substrate varies. The consequences of the varying quality of the sleeve material is not known. There are three seconds between the time that the print is applied on the material and the material is handled again, which is more than enough time for the ink to dry, without any drying unit.

Printing is performed after the sleeves have been filled. (A sleeve is first folded around the product and then the sleeve is printed.) The choice to print after filling the packaging is based primarily on the desire to have the print positioned at an exact distance from the edge of the packaging. It would not have been possible to achieve this exactness before filling the package because of the design of the machine. Furthermore, it would have been necessary to have the printer head shoot from below the package or construct an additional device to turn the package material after printing.

Eight sleeves are printed in parallel, which means that theoretically 32 printer heads would be needed to print in four-color. However, in order to increase the print speed, two printer heads are positioned one after the other, printing every second pixel by turn. This solution implies a need for 64 printer heads and a maximum print speed of around 60m/min. This corresponds to a maximum of around 8400 products that can be printed per hour with the total machine set-up. The printing system is used at an indoor temperature (20°C) and 50% RH. The equipment has been exposed to temperatures of up to 43°C on hot summer days without a disturbance in performance. U2 has no experience using the equipment at lower temperatures.

The packaging machine operates 24 hours a day and is positioned inline with the manufacturing equipment. Products produced by the main line have to be manually cared for if the packaging line breaks down. However, the packaging machine is designed to have a higher capacity than the manufacturing machine so that it does not become a bottleneck. Typical changeover times between two different products on the main line can take between four and 50 minutes.

Reliability

U1. When the printer was new, nozzle blockings occurred every five seconds. Improvements have been made since then, which have led to the achievement of a stable process that fails less often. Today nozzle blockings appear around two times per hour. In 90% of the cases, it helps to slow down the speed or stop feeding for 30 seconds in order to repair the fault. In 10% of the cases, the heads are also in need of cleaning, which takes one additional minute. An operator has to inspect the printing process at least once a minute because of the risk for nozzle blocking or side shooters.

When the web is stopped, unhardened ink located in the area where the web is directed vertically starts to course and on the flat areas the print get blurred. Hence, this part of the substrate has to be removed in the converting stage. When the operator notices a misprint, he stops the press and marks the web with a green label. The press is thereafter directly restarted or cleaned and restarted. Hopefully, the nozzle blocking has disappeared. If not, this process is repeated. When the failure is repaired, the operator marks the web with a red label. Thereafter printing and the rolling up on the end-reel is continued without removing the misprinted substrate. When the reel is converted later, the operator will notice the red label, whereby he will remove the substrate from the

web until he sees the green label. If the operator does not notice the misprint when it first happened, a lot of defect substrate could be rolled up on the end reel. This means that only the red label would be attached and thereby more attention is required in the converting stage.

U2. Sleeves (folded packaging) mistakenly touch the printer heads around 20 times per day. This means that a printer head has to be exchanged once a week and the packaging line is stopped between 15 and 45 minutes (average 30 minutes). Operators check the printing process every 15-30 minutes. U2 currently has two operators that run the packaging machine, but aims to reduce this to one operator.

Nozzle blockings are common, but this does not stop the printing process. Cleaning of the printer heads is done on average once a day when the quality drops below a certain level.

Since the printing system is newly installed, different types of problems have arisen that can be characterized as teething pains. These have been fixed, however, they still occur to some extent. One specific problem is that it is difficult to remove air from the system, which can have an affect on printer head performance. Misprinted copies because of failures are thrown away manually. Spare parts are always stored at U2 in order to assure fast repairs should anything fail.

Start up /changeover time

U1. Water canals are used to heat the ink to the right viscosity. The water is always kept at 50°C, so it is just a matter of turning on a pump to get the right working temperature. This heating process, cleaning of the printer heads and a functionality check of the printer nozzles takes around 15-20 minutes when the press is started in the morning. Ten to 30 meters of substrate are wasted during this procedure because of nozzle blocking. When the press is warm and has already been in production, you can immediately re-start printing and achieve good print quality. One problem, however, is that the printer starts from the position where it stopped, which means that the first copy will be wasted. Changing from one job to another is very fast. There is no need for press adjustments since the density does not change. The system contains one liter of ink and has to be thoroughly cleaned before a change of color can be made, which makes it unrealistic to change colors in the printer heads. In order to use specific spot colors, the flexo section of this hybrid press is used.

U2. Changing from one order to another takes three seconds if the size is similar to the previous order. Adjustments to change the packaging length take around 5-10 minutes. The height of the sleeves is always the same, which means that there is never a need to adjust the printer heads vertically. When an exchange of printer heads is made, a specific cone construction assures that it gets into the exact position. It unrealistic to

change colors in the printer heads for a specific order, since it would take several hours to clean a printer.

Preventive maintenance

U1. It is advantageous to thoroughly clean all the color bars (bars supporting the printer heads) once a month, which takes 5-10 minutes. No other special preventive maintenance is necessary. An important remark, however, is that no printer head has been changed thus far because of the newness of the system. Since this press is a pioneer, head changes have been made so far mainly because of problems that can be characterized as teething pains.

U2. Print quality gradually changes during production because of dust from the substrate and air in the printing system. Heads are cleaned once a day for two minutes on average. A six-hour maintenance action is performed every week. The quality of the print is higher after the maintenance shift. It usually takes around two days for the quality of the print to drop to a consistently lower quality level.

Operators

U1. It is advantageous for the operator to have an education in graphic production to control the printing process. A traditional printer is well suited for the job. However, it is possible to learn how to operate the press without previous knowledge (training). An operator should have the basic knowledge necessary after a one-week training course. U1 has recently educated their operators in how to repair the printer equipment.

U2. After a one-day internal operator training course, the operator will be able to supervise and clean the equipment. Electrical engineers make repairs. It is not considered necessary for the operators to have a thorough education in graphic production.

Results (packaging lines)

Equipment / production data

P1. Manufacturing and packaging are not directly linked at P1. The products are transported in tanks from the production units to the packaging lines. Employees work three shifts on the manufacturing machines and two on the packaging machines. Hence there is an over-capacity on the packaging machines. The sheet-fed machines reach a production speed of 35-48m/min (55-140 packages/min). The web-fed spaghetti machine reaches a speed of 35-45m/min (55-110 packages/min). P1 feels web-fed machines have fewer problems and are easier to supply with a new substrate. Sheet-fed machines must be attended to manually at certain intervals. Preventive maintenance is scheduled when the machine is not in production and an eight-hour cleaning is

performed each month. The production hall is kept at a temperature of 21°C and 40-50% RH, however, these values can vary slightly between summer and winter.

One type of substrate is used for all carton packaging although the quality can vary. Bad quality carton increases the risk for production stoppage. Only one type of plastic film is used for the spaghetti production. The marketing department sometimes likes to introduce new substrates and this can have an impact on production and printability.

P2. Tablets are a typical product at P2 and can be packed in blister packaging. These are inserted by a side-load machine into pre-glued carton packaging together with "product packet inserts." Batch numbers are printed inline using a flexo cliché on the aluminum foil that covers the blister. Laser is used to mark the carton packaging with the date and batch number. The tablets are produced in different production lines and stored in large bulks. They are then transported and packed in a packaging line. The packaging machines are built to have an over-capacity in relation to manufacturing. Hence, packing is not performed inline directly after production. The speed of the particular packaging line described above is 170 products/min, which corresponds to around 14m/min. The average speed of a carton packaging line is around 200 packages/min, which corresponds to 25m/min. The temperature in the production hall is 20-22°C and the relative humidity is 8-10% in the printing area. A conditioning unit (which holds a RH of 30-40%) will soon be installed since there is a problem with the paper substrates curling. A major cleaning is performed every 30 days, which takes around eight hours. Because of long changeover times due to administrative requirements, there is a lot of time for maintenance between orders. The equipment is also serviced every month.

P2 would like to use the same type of carton for every order, but this is not always possible. Suppliers sometimes change the varnish on the packaging without informing the purchaser and some countries send their own packaging manufactured from different types of carton. This spread of different substrates affects print quality.

P3 packages milk in flexible packages on web-fed packaging lines at a rate of 4500 packages/h. This corresponds to around 12-15m/min. Reel changes are made automatically without stopping the machine. The speed is doubled for newer web-fed machines. P3 uses sheet-fed packaging machines (gable-top packaging) for their other liquid products. These machines reach the same speeds as the packaging lines for milk. Newer machines, however, are today reaching speeds of up to 12-15,000 packages/h. The packaging machines at P3 operate at an over-capacity in relation to the incoming primary products. The production hall is kept at an indoor temperature of 20°C and 50% RH. After the "best-before" date is printed on the packages with solvent-based ink they are moved to a cold-storage room (4°C), whereby condensation arises on the packaging surface

Production and packing of milk and similar products such as yoghurt, etc., are made inline, while butter and cheese products are stored in a buffer before packing. It is of crucial importance that these machines are kept running to ensure the stability of the desired composition of the ingredients. The same substrate is used for all packages in each production line, meaning that the same type of material is used for the outer packaging. Inside barriers can vary between different products. Machine operators perform the daily cleaning of the machines and an outside firm comes in twice a year to perform routine maintenance and service.

Reliability

P1. A production line has 5–10 stops per day (8h) on average, which corresponds to a total stop time of 30 minutes. There is a higher risk for more stops if the quality of the carton packaging is poor.

P2 has an average of two 15-second stops per hour because of packaging getting stuck in the machines. Stops can, however, become very time-consuming if something else goes wrong. These longer stops equate to two hours every 50 hours on average and can be due to human error if the wrong article number was entered at set-up.

P3. The efficiency of production is measured at 90% (all stops and changeovers are included). No statistics on stoppage because of failures exist because there are so few failures. The production facility has to operate at all times since there is a constant flow of milk, however, there are six productions lines so production can continue even if there is a failure on one line.

Start-up / Changeover time

P1. A changeover time of one hour including cleaning is needed to change the product. Changeovers are made every four hours on average. To start-up again takes a matter of seconds.

P2. The machines are normally cleaned and ready for a new product within one hour, but because of strict regulations, the previous order has to be recounted and checked-off before a new order can start. This procedure involves a lot of time-consuming administration and increases the total changeover time to four-five hours. The actual start-up time takes less than three seconds when the line is ready.

P3. A change from one product to another is often made while the line is running, for example, when changing from low-fat milk to standard milk. This procedure takes around 10-15 minutes. Other changeovers occur two-three times every 24 hours whereby the production line is stopped and cleaned for one hour. The actual start-up time afterwards is less than a minute.

Removal of defective products

P1. A certain number of controls for the packaged product are made inline: the bottom is sealed and the weight and content of metal (screws, etc.) is tested. The package is automatically removed from the line if a failure is detected.

P2. Removal of defective products is done inline by checking the readability of the printed information (batch number, dates) with cameras. If a product is identified as defective, a special device automatically removes the product from the packaging line. The tolerances for the cameras that check the print are set very tight, which means that 1% of the packages are mistakenly removed. Only a negligible part of the removed packages actually contain defects.

P3. A special device removes the product from the packaging line if it is identified as defective. Labels are scanned on a few products to ensure that the quality of the printed barcodes is satisfactory. However, barcodes are pre-printed on the packaging material for most products, which is the case for the milk for consumption.

Operators

P1. One operator supervises each production line and they sometimes help each other out if there is a problem at one of the lines. It is not a prerequisite for an operator to have a formal education since the company provides internal training. Operators make an hourly spot-check of the print quality of the "best-before" date printed inline by inkjet.

P2. Depending on the size of the order, two-four operators supervise the packaging lines. Some of them control the quality of product samples. One person would be enough to supervise the packaging line if such quality controls were not needed. An operator does not need a formal education since the company provides internal training.

P3. The operator's role is to supervise the production process and handle the changeovers. Operators today require more knowledge because of the more advanced technology although no formal education is required since the company offers internal education to operators. One operator supervises two packaging lines simultaneously for milk production. Each of the sheet-fed packaging lines requires one operator, because manual feeding of substrate is needed.

Analysis and discussion

A number of productivity-related factors were identified through result analysis. The paragraphs below describe and motivate these factors.

Speed

The maximum operating speed of the printing unit has to be equal to or higher than that of the packaging line so that it does not slow down the production rate. Hence, production speed is a critical factor for productivity. The results show that continuous inkjet speeds are far above those of the investigated packaging lines, while the drop on demand printer system at U1 providing a visual resolution of 900 dpi is still too slow for the fastest packaging lines. However, by lowering resolution demands, U2 has shown it is possible to print 180 dpi at 60m/min, which is a sufficient speed for all of the investigated packaging lines. As described in the "printer head" section, there are drop on demand printer heads in laboratory scales that are reaching linear speeds of 63m/min and providing 600 dpi. This indicates that increased print speed along with high print quality is on its way. One possible way to retain full speed on a fast sheet-fed packaging line would be to have two parallel lines in the first section of the machine merging into one line before the actual packaging machine is fed. The speed will thereby double and the risk for complete stops decrease since it would be possible to run the packaging line at half the speed should one printer fail.

Reliability

Integrating a printer system into a packaging line means that an additional device has to interplay with the existing packaging line. It is important to have a reliable printer system so that the production flow is not disturbed. Reliability demands are crucial when products are manufactured without using a buffer before entering the packaging line. One example is the milk production at P3. Moreover, if a new printing technology is to be introduced within the pharmaceutical industry, it is very important to assure that the technology is stable in the long term. An introduction of a new technology that might affect the products necessitates approval by authorities in numerous countries, which can take several years. Good reliability implies lower failure frequency and shorter stop times, which lead to higher productivity.

Stop times correspond to an average of 30 seconds twice an hour for U1 and 30 minutes once every 168 hours for the printer systems at U2. Start-up times for the packaging lines are in general very short, but since an operator needs to be in place and set the machine running, the procedure may take a longer time.

It is possible to make the following calculations using the above facts and the prediction of 30 seconds for start-up time:

- Stop time per hour using the printer system at U1: [2*0.5 minutes (cleaning) plus 2*0.5 minutes (start up)] = 2 minutes

- Stop time per hour using the printer system at U2: [1/(24*7)*30 minutes (repairing) plus 1/(24*7)*0.5 minutes (start up)] = 0.2 minutes.

The calculations show the importance of having short start-up times if the printer system fails frequently.

The corresponding figures for the packaging lines are 3.8 (30/8) and 1.2 minutes/hour [120/(6*2*8)] for P1 and P2. Data is missing for P3. According to this simple analysis, the stop time because of failures could increase by 170% if the drop on demand printer system at U1 is used and 30 seconds are needed to start the packaging line. This is, however, not a complete analysis since a stop because of a failing printer head may also result in additional disturbances in the production line. For example, the results show that a stop in the printer system implies a disturbance in print quality. It is likely that even more time will pass for disposal of the misprinted items.

Other failures in the printing equipment occur besides those originating from nozzle failures, etc. Problems that have been identified as teething pains have occurred mainly because the case study printing systems were installed relatively recently. It is difficult right now to know whether these problems will completely disappear or if there is a weak link increasing average stop times per hour. It would be interesting to compare the stop times for these other failures with the nozzle failure stops but that is out of reach for this study.

Operator qualifications

The results show that it is important to have spare parts and the necessary competence in-house to assure fast repairs when striving for high productivity. As has been done at U2, a technician/engineer could be assigned to make the repairs, or the packaging line operator could take on the role of repairperson, which is the case at U1. The latter alternative would mean that an operator's qualifications would need improvement.

Improving an operator's qualifications would be advantageous to properly operate the printing equipment and assure a high print quality. U1says it is beneficial to have a proper graphic arts education to completely control the printer equipment. They mean however that it is possible to get the knowledge necessary to operate the printer system after a one week course. Operators currently do not possess any special graphic arts knowledge at U2, but since more focus will be put on improving print quality, an improvement in the operator's qualifications might be advantageous. Hence, if high

quality inline printing starts to spread, more knowledge in graphic arts production would likely be demanded from operators.

Supervision

The printing process must be carefully supervised to quickly detect misprints when print quality is a priority. Fast detection means that operators can maintain the best possible productivity should a failure appear. The printing process has to be supervised at all times when products are sold to consumers with high print quality demands (U1), while products for the business-to-business segment require less frequent supervision (U2). Since the packaging line is always supervised, it would be possible to introduce this additional task without the need for additional resources. However, when one operator supervises two packaging lines simultaneously, as in the case of the web-fed lines at P3, more personnel might be needed. An alternative or complement to operators supervising the process is to install a vision system, such as the one P2 uses to scan batch numbers. Print quality demands determine tolerance levels. However, scanning larger, more sophisticated color prints would demand more advanced systems and a thorough investigation of what is available on the market would be needed. The results show that the vision system that scans batch numbers at P3 is mistakenly wasting 1% of their packages. Therefore, it might be advantageous to have a combination of a vision system with manual checks of rejected packaging.

Start-up time / Changeover time

The time required to change from one job to another on the printing equipment is negligible compared with the changeover time on the production lines. Hence, printer-related activities on changeovers do not affect the productivity of the production lines. At U1, the printer system needs to be turned on before the packing line is started since it takes 10-20 minutes to get the system running after it has been turned off. The printer system at U2 starts directly.

Climate

The results show that the printer system works well at indoor temperatures and 50% RH. Higher temperatures (40°C) do not seem to affect performance, but the equipment should not be run in colder temperatures, such as in a cold-storage room, since the equipment calibration can decay. Low-temperature inkjet inks that may eliminate these problems are in development (www.labelsandlabeling.com). There is no need to print in a cold-storage room at the investigated production lines, but it is important to assure a fast ink drying time since packages are packed together at the end of the production line or stored in a cold storage room (P3) where condensation can appear on the packaging.

Print quality aspects

The result shows that production stops vary depending on the print quality demands. Between U1 and U2, there is a factor difference of five-six in stop times because of

failures. Print quality demands are lower at U2 where products are sold business-to-business, which means that many small stops due to nozzle blocking are avoided. Hence, print quality demands affect productivity.

The results indicate that pharmaceutical packaging has the highest demands on print quality while other consumer packaging (within the food industry for example) is in second place. Products sold business-to-business have the lowest quality demands.

The studied producers are generally running the same type of substrates on their packaging lines to keep to a standard. However, the difference in substrate quality between suppliers may have an impact on print quality. Customers sometimes deliver their own substrate to be used in the packaging line at P2, which affects the print quality. Therefore it is advantageous if the printer equipment can print on different types of substrates. A special coating is applied on the substrate at U1 before printing which implies that it is less important to have a uniform substrate quality. However, since UV-curing inks are used, migration problems have to be considered if food or pharmaceuticals are to be packaged.

The results show that it is not realistic to change colors in the printer heads to meet the demands for specific spot colors. U1, who uses a hybrid printing solution, finds it is possible to print spot colors by using one or more flexo clichés. This is also possible at P2, who uses a cliché to print on blister packaging. However, flexibility would decrease with a static printing form and the advantages of having a non-impact printing method would disappear.

Preventive maintenance

Preventive maintenance is important for productivity and assures that the printing equipment will work properly. This activity can easily be coordinated with preventive maintenance activities performed at the packaging lines.

Adapting production lines

It is important that the printing unit can be integrated into existing production lines, since the investment cost of packaging machines is high (Andersson, 1997). Because there is a higher risk of failure when a printing process is added to an existing packaging line, it is important to assure that there is sufficient over-capacity to catch-up with the production schedule when printer failures appear. All investigated companies (U2-P3) have over-capacity in their packaging lines in relation with manufacturing.

Since stops in the packaging line imply disturbances in print quality, there is a need for a device in the packaging line that can remove misprints. This can be carried out before or after the package is filled (assuming printing is done before filling). As the results show, P1, P2 and P3 already have such a device in place, after the filling. Removing misprinted packaging after filling would therefore not demand any major extension of

the packaging line other than a control of which products are waste. This means that packaging can be removed without stopping the packaging line, which is a prerequisite to avoid additional disturbances in print quality. According to U1, these appear when UV-curing ink is used and the web is stopped. U2, who prints with oil-based inks without any drying unit, has no such problems. The substrate can be removed before filling without disturbing the feeding process in sheet-fed machines, while in web-fed machines, misprinted parts need to be cut away somewhere in the middle of the web, which can be difficult. However, it is cheaper to discard empty packages rather than those already filled. Because 10-30m of the substrate needs to be removed when the printer system is started at U1, many filled packages would be removed unless it is possible to remove misprints before filling.

Considering that a filled package is three-dimensional, it would be easier to print on the packaging before it is formed and filled in the packaging machine. Unlike pre-glued cartons, flat blanks or flexible packaging material make it possible to print over the entire package using printer heads directed to shoot droplets in one direction. Printing before filling would not require any extra adjustments of printer heads to adapt to different packaging heights.

Because printing is performed on the package after filling at U2, there is a risk of it opening up and touching the printer head. The distance between the printer head and substrate has a small tolerance to ensure good print quality. Therefore, it might be advantageous to print before filling since it is more likely that a flat substrate will keep within the tolerances better than a filled and sealed package.

It is important to have the print positioned an exact distance from the edge of the package at U2. Since the machine sets the limits on exactness, printing has to be made after filling to achieve this exactness. Furthermore, an additional device would be necessary so that printing from below would not be necessary, which is not suitable for drop on demand technology. Hence, the design of the existing packaging line can be the deciding factor on whether to apply the print before or after filling.

There is a need to keep track of individual packages if the printed information is customized for a very short series or for individual packages. For example, if a package is rejected because of a misprint or incorrect assembly, this particular package has to be reproduced. New market demands at P2 make it necessary to keep track of individual packaging. A thorough inspection of rejected packages could assure that all individual packages are produced.

Open questions

This paper focuses on the opportunities using inline printing even though offline printing might be advantageous in different situations. A comparison between the printing types would accordingly be interesting for future research. Since costs are the

deciding factor in most cases, a comprehensive overview of costs would also be interesting.

There is a chance that some data was not reported in this investigation since some of the companies have developed special processes and technical details that they want to keep to themselves. Only two users are included in this study even though leading technology has been investigated. Furthermore, the technology is developing quickly. According to Veresh (2003), the evolutionary process is driven by technology improvements that imply better quality, higher speeds and reliability.

Conclusions

The analysis shows that the following factors should be considered to achieve high productivity when a high-speed inkjet printer system is to be integrated into a packaging line.

Productivity related factors in high-speed inkjet printing:

- Print speed
- Reliability
- Print quality demands
- Operator qualifications
- Preventive maintenance
- Right climate
- Supervision

Critical factors in packaging lines

- Start-up time
- Reliability
- Sufficient over-capacity
- Operator qualifications
- System for removal of misprints
- Number of different substrates

Acknowledgment

The author would like to thank the companies studied for their kindness, courtesy and cooperation. Furthermore special thanks are given to my supervisor at KTH, T2F-mentor and colleagues at STFI-Packforsk for their valuable comments. The financial support from the Swedish national research program T2F, the Swedish Graphic Companies' Federation and EU are gratefully acknowledged.

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Appendix 1: Interview guide (packaging lines)

Characteristics of packaging lines - basis for discussion

Placement:

- Space around the packaging line
- Relative humidity (RH)
- Temperature
- Need for suction fans
- Dust

Productivity:

- General length of production series?
- Costs for an inoperative packaging line?
- Speed?
- Supervision of the production?
- Actions necessary if the production line is interrupted?
- Start up time?

Operators:

- Number of operators
- Education
- Preventive maintenance

Packaging /product:

- Substrate

Print quality

- Existing printing technology
- Print quality demands
- Wearing problems during packing together
- Stock keeping
- Transportation

Restrictions

- Restrictions for hazardous substances

Appendix 2: Interview guide (users of inkjet printing equipment)

Ink jet printing systems

- Advantages experienced from online printing?
- Type of equipment
- Type of ink
- Number of different substrates?
- Type of substrates?

Location

- Level of moisture (Maximum operating window)
- Temperature (min-max operating window)
- Size of the ink jet printing system
- Peripheral equipment
- Need for suction fans
- Dust or particles in the air

Productivity

- Speed of the production lines (min, max average)
    - Variable speed?
- Production volumes (min, max, average)
- Changeover time (between different orders)
- Volume(meters) of substrate wasted due to adjustment of the press when staring up?
- Time for drying?
- Risk for interruptions (failures in the printing process)
- Stop times
- Actions necessary if the production line is interrupted?
- Start up time for the production line?
- Service time (ex. Change of print heads + what else?)
- Frequency of service needed

8.1 Operators

- Education needed
- Level of supervision needed
- Preventive maintenance
- Number of operators needed

Quality

- Resolution
- Color reproduction
- Color /substrate penetration
- Precision of the print (+- x mm?) (problems to print exactly where intended?)
- Sensitivity for dust
- Opportunities of changing colors
- Number of colors (process, hex, PMS?)
- Adhesiveness of the ink on the paper
- Technology used to pre-print packaging material?