THE COST OF PRINTING A CORRUGATED BOX

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ABSTRACT

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Flexography, lithography and digital are the three basic printing technologies used to apply graphics to corrugated boxes. The purpose of this research is to identify the primary cost drivers of selection of a particular process to print corrugated boxes. Flexo post-sheet, flexo pre-print, litho-lamination, and litho-labeling are the four processes traditionally used to print corrugated boxes. Digital printing processes have been recently introduced to the industry.

This research explores the estimated cost of producing a printed corrugated box using the traditional processes with special emphasis on the relative cost of low volume printing. It compares the direct and indirect cost in a cost structure, process drivers in adoption of a printing process and the closest competitor to digital printing. Cost estimation results reveal that volume is one of the primary drivers in the selection of a printing process, if the primary criterion for selection is the unit cost of production. Quality and speed are the other process drivers. For all the traditional processes, fixed direct cost is a big part of total cost as opposed to variable direct cost for short volume of up to 1500 units. Due to this reason digital printing is very cost effective in low volume up to 500 units. When cost, quality, and speed are taken into consideration, the process that is most similar to digital printing is litho-labeling. Additionally, digital printing offers other benefits such as customized printing or variable data printing.

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Introduction

The purpose of this research is to identify the primary drivers of selection of a particular process to manufacture and print corrugated boxes. This research also explores the estimated cost of producing a printed corrugated box using the traditional processes, with special emphasis on the relative cost of low volume printing.

Conventional "brown box" shipping containers comprise a majority of the corrugated board production. A significant proportion of these are printed with simple 1-2 colors (up to 4) using flexography. The printing occurs concurrently with cutting, scoring, and gluing along the manufacturer's joint, in a specialized piece of equipment called a "Flexo-Folder-Gluer" (Shulman 1986). The flexo-folder-gluer is a high speed machine and produces high volume with limited color reproduction compared to litho and digital printing processes in a cost effective way. The printing methodology using this machine is called flexo post-sheet printing.

Two factors have contributed to a shift in the cost of printed corrugated board. There is an increase in the number of colorful displays, and have a much smaller run size. About 6% of corrugated fiberboard is used in colorful point-of-purchase (POP) displays. This is a segment of the market that is growing, and represents the highest value (per square foot) of corrugated packaging produced (Slembrouk 2007).

A number of factors influence the cost of color printing methods including prepress time, set-up/changeover costs, press production, and post-press operations (Ruggles 1996). Customers are moving to just-in-time and zero inventory and as a result the industry is moving away from traditional long runs to shorter runs. Shorter product life cycles and fragmentation of product markets have reduced the average print run to below 5,000 sheets with few repeat orders. In some cases, the total annual set up time is longer than the annual net production time (Slembrouk 2007).

The quality of color print on corrugated board is sensitive to the texture of kraft paper, the “washboard” effect from the corrugation, and the uneven absorptive capacity of the substrate. As a result, printing methods have grown increasingly sophisticated. The highest quality colorful printing requires a “white top” bleached or clay-coated substrate to better reflect the colors and provide contrast.

In contrast to post-sheet printing (using flexo post-sheet), the paper can be pre-printed (using flexo pre-print, lithography or gravure) before the board is combined or a pre-printed label can be applied after the board is combined. Pre-printing is an expensive option because of the scale requirement for a long run length to break even, which is not consistent with the increasing demand for flexibility. A high-quality printed label can also be pasted on the combined board. These labels are usually referred to as “litho-labeling” because most are printed by offset lithography, although rotogravure, and increasingly, flexography are also used for labels. The additional operation of laminating or gluing the label to the corrugated substrate is economic only for short, high value runs. (Cartellieri 2008, Eldred 2007)

Since the 1990s the speed, print quality and the number of color reproduction capabilities of flexographic post-print process (after the board is combined) has improved significantly, and can print as many as eight colors. But flexo post-print has a high production cost because of the high cost pre-press operations and long set-up time. Also, it weakens the board because it crushes the corrugated flutes. Furthermore, register deviation, dot gain and the washboard effect are hard to prevent. (Massimo 2009)

The introduction of digital printing adds an attractive option for short POP (Point of Purchase) runs. New generation digital printers can produce “lithography like” print quality. Without the need for prepress steps like producing films and/or plates, the total upfront cost has been reduced. As no plates are used in the process, set-up/changeover time and the start-up time can be reduced to minutes.

However, there is no cost comparison to clearly show the difference in economies of run length for the different printing technologies. This research explores the estimated cost of producing a printed corrugated box using the traditional processes, with special emphasis on the relative cost of low volume printing. The research also explores the main drivers affecting the adoption of a printing technique for a corrugated box production. The drivers involve run length, speed and quality. The research also compares and evaluates the potential of digital printing to compete with other printing methods.

Chapter 2

Method of Printing on Corrugated Board

There are three basic printing technologies used to print on corrugated board. However there are a total of five methods to apply graphics to corrugated board based on whether the linerboard, label or combined boards are printed. The following five methods will be discussed:

2.1 Flexo post-Sheet printing

2.2 Flexo pre-print

2.3 Litho-Lamination

2.4 Litho-Labeling

2.5 Digital Printing

2.6 Die-Cutting

2.1 Flexo post-Sheet printing

Flexo post-sheet printing is the most common process in which the combined corrugated board is printed directly. It is typically used in the flexo-folder-gluer which is a corrugated box-making machine. The machine has the capability of one-pass multi-color flexographic printing, scoring, slotting, die-cutting, folding and gluing the manufacturer's joint. Corrugated blanks that have been scored in the cross flute direction in the "sheet plant" are loaded on the feeding side of the machine. A printed, folded and joint glued box comes out on the delivery side of the machine.

The unique thing about the flexography printing process is that it can print directly on the corrugated board. Digital printing is the only other process which can print directly on corrugated board. Flexography is simple, fast and economical.

Flexographic printing produces a lower quality image compared to lithographic and digital printing. Among all the processes, flexography post-sheet printing has the lowest quality (Barnes 2011). Flexographic printing has lower resolution than litho process. The printing resolution for flexography is about 48 lines/cm (120 lpi) using conventional production methods, as compared to 60-120 lines/cm (150 up to 300 lpi) for the litho process (Kipphan 2001). The corrugated board has an uneven surface due to the flutes which makes the board surface difficult to print and results in a "washboard effect". Furthermore, the brown color of kraft paper does not reflect colors well as white paper does and cannot offer vivid color, and pressure at the nip weakens the board by crushing the flutes of the board.

Research conducted at Rochester Institute of technology confirmed the reduction in compression strength of a corrugated box printed with flexo post-print process. A reduction in compression strength from 2% to 24% was noticed in flexo post-printed boxes when compared to flexo pre-printed boxes printed with different combination of thick and thin plates and one color and three colors printed. 24% reduction in compression strength was noticed after testing 15 corrugated boxes printed in three colors with a thick printing plate. According to the research, flexographic printing plates can be classified as thick plates and thin plates. Plates thicker and thinner than 0.250" are called thick plates and thin plates respectively. A 17% decrease in compression was noted between the boxes printed thick printing plates versus thin printing plate. A further 11% reduction in compression strength resulted between one color and three colors printing using a 0.250" thick plate (Sriratbunterng 1998).

The flexographic printing process has a resilient relief printing plate made of rubber or photopolymer which enables printing on rough and wavy corrugated surfaces. Flexography was developed in order to print on uneven surfaces such as corrugated board using a rubber stamp mechanism. The printing plate act as rubber stamp and accepts ink from an anilox roller and transfers it to the substrate by the pressure of the impression cylinder.

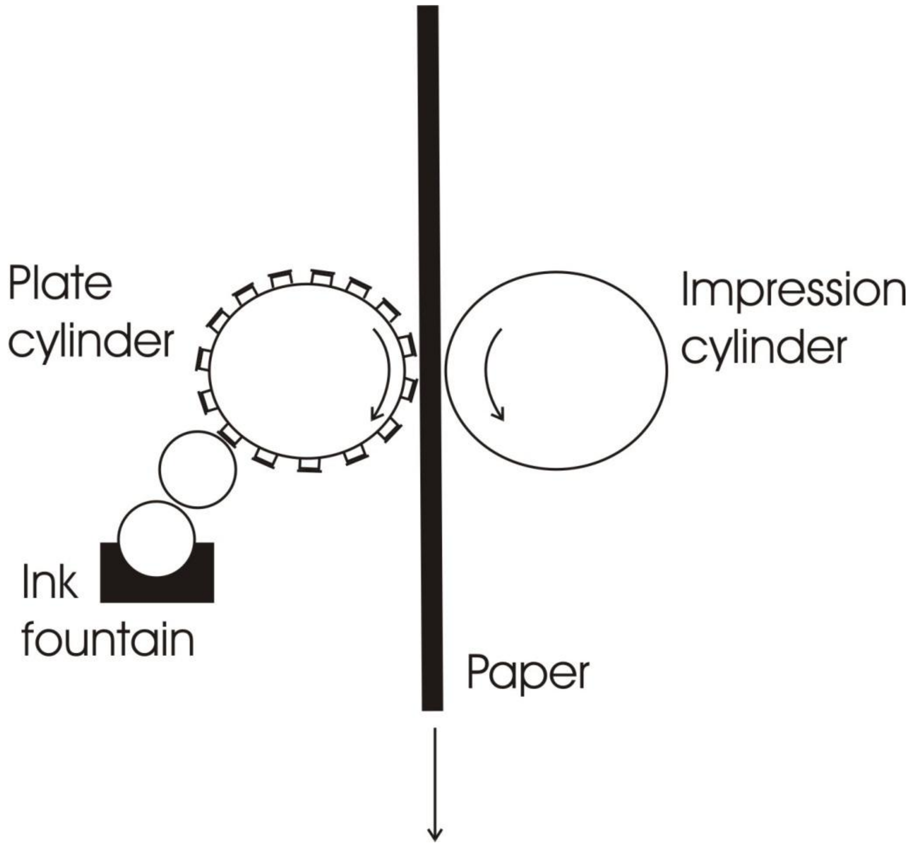

Figure 1: Flexographic Printing Process (Twede and Selke 2005)

As shown in Figure 1, the print station is the housing unit for impression cylinder, plate cylinder, anilox roller and ink fountain. A flexo-folder-gluer can have any number of print stations for a multi-color printing job but most new machines have three to five color capabilities (Perkins 2000, Schnell 2000). The main parts of a print station are:

2.1.1 Ink Supply System

2.1.2 Anilox Roller

2.1.3 Printing Plate and Cylinder

2.1.4 Impression Cylinder

2.1.1 Ink Supply System

The ink supply system applies ink to the printing plate. Water based inks are used in this process which have a tendency of drying quickly, so a continuous supply of ink is maintained to the anilox roller. Ink is supplied in pails which act as a reservoir of the ink. A pump assembly is used to transfer ink from the pail to the ink pan. The ink pan holds a small quantity of a continuous supply of ink. A part of anilox roller submersed in the ink pan and picks up the ink from there. A doctor blade wipes off the extra ink picked by the anilox roller and makes an even layer of ink on the anilox roller.

Controlling the viscosity of the ink is very critical for the printing process. Naturally, ink viscosity increases during normal operation. The cost of printing can go up if high viscosity inks are used on the press. Water is added to balance the viscosity of the ink. Water caused the ink pH to go down, so a proper mixture of water and amines are used to adjust the ink viscosity and pH.

2.1.2 Anilox Roller

The anilox roller is the most important part in the inking system. It controls the ink metering process and supplies an even film thickness to the plate cylinder. It is made of steel and is chrome plated or ceramic coated to improve the life and performance of the roll. For more stiffness and lighter weight, carbon fiber anilox rolls are also used. These rollers are about 40%-60% lighter in weight compared to conventional steel rollers (Perkins 2000, Schnell 2000).

Anilox rollers have tiny engraved cells on its entire surface along the length of the roll. These cells are so small that generally they cannot be seen with the naked eye and even cannot be felt by sliding one’s hand on the surface of the roll. These tiny cells carry ink from the ink pan to the plate cylinder.

In order to change the color on an ink station or to halt the machine for a longer period of time, the ink station has to be cleaned. Water based inks has the tendency to dry very quickly on the anilox roller. Dried ink is hard to clean and increases the set-up and change-over time. After every run of the machine, immediately, a flexo cleaner is circulated through the inking system. The cleaner is a mixture of mild detergent and warm water having a temperature range of 100 – 140 °F (Perkins 2000, Schnell 2000).

2.1.3 Printing Plate and Cylinder

The printing cylinder is made of steel and holds the rubber printing plate. It serves as a host to the printing plate to facilitate the ink transfer from the printing plate to the substrate.

Printing plates are made of rubber or photopolymer. Rubber plates are made by curing natural or synthetic rubber in a mold. Whereas commonly used photopolymers plates are made up of a light sensitive material. The image is developed by exposing the plate to ultra violet light through a photographic negative. When light hits the photopolymer plate, the image area is hardened and the non-image areas remain soft and dissolve out in a developing solution. The image areas remain in the relief form and hence only image areas accept the ink and transfer it to the substrate.

Another method of making a flexo printing plate is by laser engraving. A computer controlled laser engraves the image on the plate. These plates offer unmatched quality comparable to the gravure printing process but because of its high cost of production, they are not common in use. (Perkins 2000, Schnell 2000)

Once the printing plate is ready, it is mounted on the printing cylinder using different mechanism depending on the machine manufacturer. One common method involves using double sided tapes to mount printing plate to the printing cylinder. Once the printing station is ready, operator adjusts the slotting and scoring section of the machine. In order for the box to get its shape, the box blank has to be scored in both vertical and horizontal directions. Flexo-folder-gluer is designed to score only in one direction. Scoring in other direction is done at corrugated blank manufacturing plant. Hence, flexo-folder-gluer receives blanks already scored in one direction.

In the slotter/scorer section of the machine, blank is scored to create four body panels of the box, slotted to create top and bottom flaps and create the manufacturer joint to join the box to the fourth panel. Set up of the slotter/scorer section can me manual, semi-automatic and fully automatic. Multiple male and female scoring heads are mounted on two shafts of the flexo-folder gluer machine in the slotting/scoring section. As the blank passes through these shafts, the scoring head creates a crease or score on the blank. The profile of scoring head and the pressure between the male and female scoring heads defines the quality of the score. Immediately after scoring, blank passes through another pair of shafts loaded with male and female slotting heads. These heads trim the outside edges of the blank; create top and bottom flaps and a manufacturer joint.

After all the printing, scoring and slotting action, blank enters into the folder gluer section. In this section, blank is folded to fasten manufacturer joint to box using glue application. Folding of the blank is done by adjustable folding rods and belts with steel rails. Adhesive is applied to secure manufacturer joint to the box. Adhesive application is either done by nozzles or a wheel glue applicator. At this point, the corrugated box is ready in a knock down position. The box moves further to the delivery section where multiple knocked down boxes are stacked up and strapped together to ship to the warehouse.

2.1.4 Impression Cylinder

The substrate is pressed between the impression and printing cylinder. The impression cylinder provides counter-pressure to the printing cylinder necessary to transfer ink from the printing plate to the substrate. It is also made up of steel and rotates at the same speed as the printing cylinder.

2.2 Flexo pre-print

In the flexo pre-print process, the top liner of the corrugated board is printed before the board is combined on the corrugator machine. The flexo pre-print process uses the same printing technology as post-sheet process i.e. flexographic printing.

In the pre-print process, flexographic printing yields better print quality than the post-sheet printing method. However, the print quality for both processes is not as high as the lithography process (Barnes 2011). Since the pre-print process provides a smoother surface for printing, the quality is better but lower than lithography due to lower screen resolution. This printing process has a resolution of 120-133 lpi (Eldred 2008).

Quality is also better than post-printing because of the use of white-top linerboard which has one side white and other side brown. The white surface reflects more colors than brown kraft and helps to produce more vivid colors with better quality.

The process requires a very high volume of print order to make the process economical. For an independent corrugator, one truck load of preprinted paper rolls is required to justify the plates cost and other cost drivers (Barnes 2011). This process has a very large initial capital investment for the machinery. The machinery includes a high speed multi-color flexography printing machine. The machine can cost as much as a corrugator machine. Hence printing and corrugation is done mainly by integrated convertors rather than independent.

For pre-print, the flexographic printing press can be wide web or narrow web. Wide web presses are of generally 110” to 130” wide and narrow web presses are 30” to 60” wide. These presses are capable of printing 4 or more colors.

Like post-print, printing plate is a big cost factor in flexo-pre-print. Pre-print plates can cost somewhere from 5000 to 25,000 USD for four colors (ICPF 2011) depending upon the size of the machine. Set up time and cost is also huge. Hence, a high volume is required to justify the total cost of the process in order to make boxes cost effectively.

The flexo pre-print is an indirect process where post-sheet is a direct process. In pre-print, the web is printed first and then it serves as a feed stock for the corrugator machine as a top liner where it is combined into corrugated board. The printed stock is mounted in the corrugating machine as the top linerboard, and two other webs of unprinted stock are also mounted serving the medium and the bottom linerboard for the corrugated box. In the delivery station, a printed combined corrugated blank is received as the output. The blank is then further processed either in a flexo-folder-gluer or in a specialized piece of equipment which serves the slotting, scoring, die-cutting, folding and gluing functions. Cutting dies is also a big cost factor in this process.

2.3 Litho-Lamination

The third process used to print corrugated board is known as litho-lamination. It is an indirect process and uses lithographic printing, also known as “offset” or “litho”. Top liner sheets are printed separately in an offset printing press and combined with a single-face corrugated board in a different machine. Hence it is a combination of two different process, printing and combining into single wall corrugated board.

Two types of adhesives are used in litho-lamination process. Starch based adhesive is used to combine medium and bottom linerboard in the normal process used to make a single-face corrugated sheet. PVA (Poly Vinyl Acetate) is used to combine the printed sheet and single-face corrugated board. Starch is a water-based adhesive and the moisture in the adhesive can cause the fibers of the board to expand. Expansion in the fibers can produce a wavy surface. This wavy surface is not appropriate for the appearance of high quality graphics on corrugated board. To avoid the wavy effect, PVA adhesive is used on the top side (Barnes 2011). PVA is a synthetic adhesive and more expensive than starch adhesive. The moisture content of PVA adhesive is very minimal compared to starch based adhesive and does not interfere with the surface texture of the board. It results in a smooth surface of the corrugated box. Also, heat is needed to faster the curing process of starch adhesive. Heat can produce undesired burning effects on the sheet and reduce the print quality. As the top sheet is litho-printed and glued with PVA adhesive, it gives a high quality corrugated board with high quality graphics.

Offset printing offers a very high quality print and among all the process, litho-lamination has the best print quality (Barnes 2011). Lithography has 150 lpi or better screen resolution. The substrate used for printing almost always has a white top and comes in different varieties. A common type of substrate which is the brightest white is a solid bleached sulfate kraft paper having a white clay coating on one side which is the printing side.

Litho-lamination is used for fairly long runs but much shorter than flexo pre-print. The minimum quantity to make the process economical is around 20,000 prints and there is no maximum number of prints. It can go up to a million print or more (ICPF 2011). However, the process would not be as economical as flexo pre-print process for such a large quantity.

The lithographic (offset) printing process uses a metal printing plate on which the image areas and non-image areas are chemically separated, unlike flexography where they are physically separated. The ink is solvent based (unlike flexo's water based ink), and process works on the principle that oil and water repel each other. Image areas on the printing plate are oleophilic/ink accepting and hydrophobic/water repellent where as non-image areas are hydrophilic/water accepting and consequently oleophobic/ink-repellent. Water solution is applied first which causes the non-image areas to repel ink. Image areas on the plate are made up of a chemical which has properties to repel water. Ink is applied afterwards to the printing plate, sticking only to the image areas. The water does not let the ink to stick to the non-image areas. The inked areas are then transferred from the plate to the intermediate offset roller called a blanket cylinder, and then onto to the substrate by having the counter pressure from the impression cylinder.

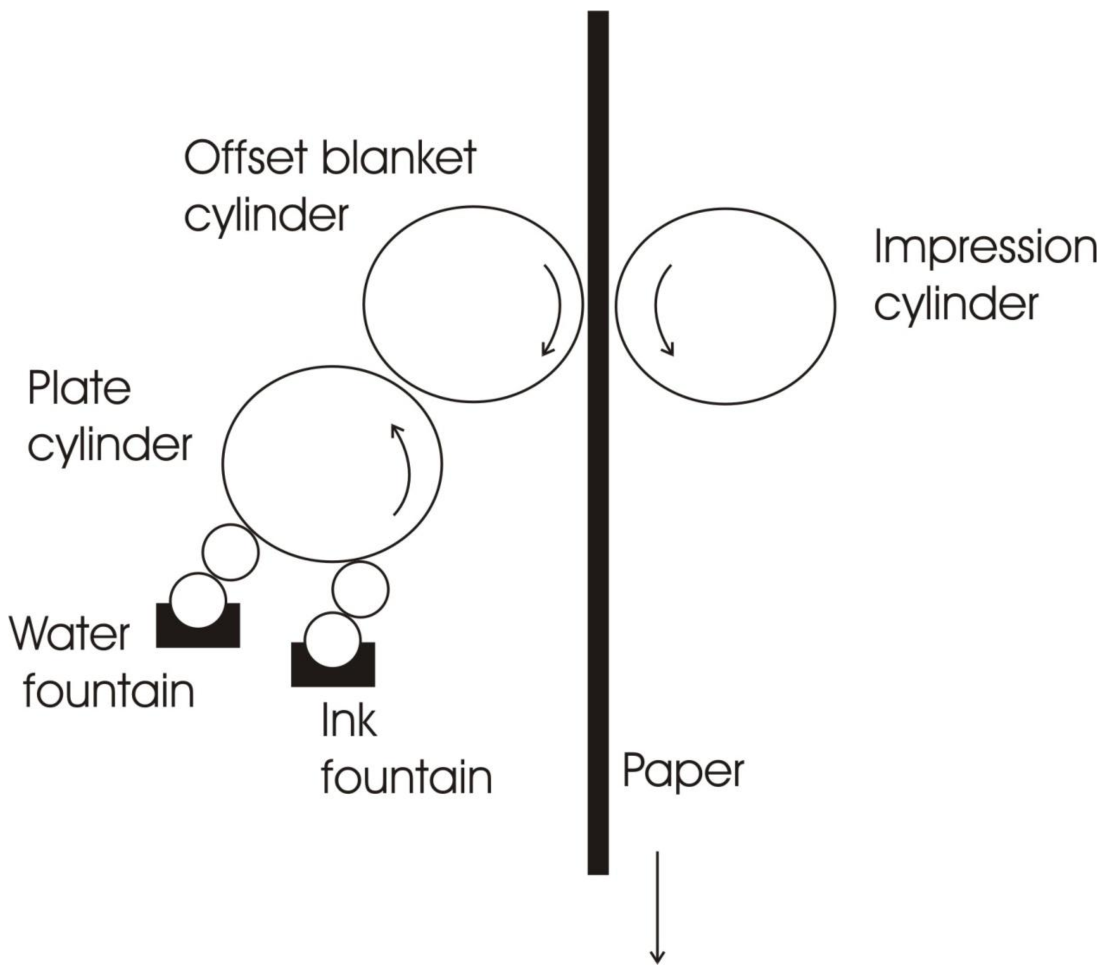

Figure 2: Offset printing (Twede and Selke, 2005)

The parts of a lithographic printing station are following:

2.3.1 Inking System

2.3.2 Dampening System

2.3.3 Printing Plate and Cylinder

2.3.4 Blanket Cylinder

2.3.5 Impression Cylinder

2.3.1 Inking System

The inking system supplies an even layer of ink to the plate cylinder. Ink is stored in ink fountain which serves as a reservoir. Ink transfers from the ink fountain to the plate via rollers. As ink is transferred between the rollers, they meter the ink into a very thin even layer which is then at last applied to the plate. The thickness of the layer of the ink that is generally applied from the plate to the substrate is about 1µm.

Printing ink for lithography is quite different from flexographic inks. Litho inks are oil based rather than water based. It is a high viscous mixture of solvent, resin, pigment, additives and other components. Due to the oil based nature of litho ink, separate ink drying methods are used to dry the ink to avoid problems like doubling, ink transfer to the top sheet and/or soiling of the sheet. Dying methods include Infra-red (IR) drying, Ultra-violet (UV) drying and Thermal or hot air drying (Kipphan 2001).

2.3.2 Dampening System

The dampening system applies a very thin layer of watery dampening solution to the printing plate. Water fountain in figure 2 acts as reservoir for the dampening solution. As the image and non- image areas are on the same level of printing plate, ink can stick anywhere on the printing plate. So, dampening solution is applied to the printing plate first which adheres to the non-image areas only due to the hydro-phobic nature of the image areas. As the ink is transferred to the printing plate, it sticks only to the image areas because water does not let the ink to stick to the non-image areas. The layer of dampening solution of about 2µm is applied to the printing plate and the dampening solution consists of 90% to 95% water and iso-propyl alcohol as an additive. (Kipphan 2001)

2.3.3 Printing Plate and Cylinder

The printing cylinder is a steel roller that houses the printing plate. It is directly connected to the dampening unit, inking unit and the blanket cylinder.

The printing plate is a crucial part of the printing station and defines the image and non-image areas. The printing plate is generally made up of aluminum. A photosensitive coating is applied on top of it, and then the plate is exposed with either positive or negative of the image under UV light. After exposure, the plate is developed in a developing solution which separates the image and non-image areas. After drying, the plate is ready to use.

The plates for offset process are cheaper than the flexographic plates. Computer-to-plate technology is used to make printing plates these days. In this technology, the image is directly transferred to the plate which eliminates the need of film positives. The machine which does all this operation is called a computer-to-plate machine.

2.3.4 Blanket Cylinder

The blanket cylinder houses the blanket transfers ink from the printing plate to paper. It is positioned between the plate cylinder and impression cylinder. The blanket is made up of a compressible material, which evens out the irregularities in the substrate and ensures a high quality image output. A blanket can run up to a couple of hundred thousand prints depending upon the type and quality of blanket and needs to be changed after that. One blanket can serve multiple jobs and it is not very expensive.

2.3.5 Impression Cylinder

The impression cylinder applies counter-pressure required for printing. The area where the blanket cylinder and impression cylinder meet is called the "nip". Pressure at the nip is very critical for good image transfer, and the impression cylinder controls this pressure. This pressure is also responsible for moving the paper through the nip.

2.4 Litho-Labeling

Litho-labeling is another printing process used to apply graphics to a corrugated board. A lithographically printed label is glued to one side of double-faced corrugated board.

Litho-lamination and litho-labeling uses the same printing principle of lithography printing. The difference between litho-lamination and litho-labeling is that in litho-lamination the printed sheet is the top linerboard of a corrugated box and in litho-labeling the printed sheet is a printed label glued on top of the top linerboard. In litho-lamination, a full size litho printed sheet is applied to single-face corrugated board. The top printed sheet serves as the top liner and needs to be able to cover the whole size of the corrugated blank. In litho-labeling, a litho printed label instead of a full size sheet is applied to double-face (single wall) board. For example, the blank size for a RSC 10"x10"10" corrugated box is approximately 20" x 42" In litho-lamination, a lithographically printed sheet of 20" x 42" size is required to serves as the top linerboard for the box. However, in litho-labeling, the top printed "label" is an extra sheet that does not constitute an integral part of the corrugated board and can be of small size like a spot label sticker. It can be of any size smaller than 20"x 42" depending upon the customer requirement.

For very large size corrugated boxes such as TV corrugated boxes, the corrugated blank size is enormous. In order to make such a box with litho-lamination with printing on the entire surface, a very large printed sheet is required along with a very large printing machine to print on the sheet. Huge flexo printing machines are available for flexo pre-print however huge lithographic printing machines are not available. Hence, to achieve a lithographic printing on a TV box, litho-labeling process is used which can apply a label on a face of a corrugated box which is significantly smaller than the blank size. If the graphics has to be applied on multiple faces, individual printed label can be used.

Commonly, a label of size of the area of the faces of box is used. In our 10”x10”10” corrugated box, it may be two labels of 10”x10” each on the front and rear face or can be a one long label of 10”x40” label to cover front, rear, left and right faces. Labels are generally not placed on the top and bottom flaps. So, a litho-labeled corrugated board can be thought as of board with 4 plies of paper.

As we are adding an additional ply of paper to the structure of the corrugated board, it may increase the compression strength of the box. Medium of a corrugated box provides most of the compression strength to the box structure. The additional ply of paper is used on the outer surface and acts as a linerboard. As linerboard does not provide significant compression strength, it can be assumed that the increase in strength should not be significant.

The first step in making corrugated boxes using litho-labeling process is to manufacture the box blank on a corrugator machine. Once the blank is ready in the required size, the blank is processed through a labeling machine. Labeling machine uses synthetic adhesive such as PVA and sticks the label to the corrugated blank. As mentioned earlier, labels are printed at a lithographic printer. After combining label and blank, it is processed through a die-cutter and a final knocked-down box is prepared.

Litho-labeling process can be used for low volumes. The minimum quantity for the process is generally assumed to be at least 500 prints and it can go up to 250,000 prints for the process to be financially effective (ICPF 2011). If the graphics often change, then the process proves to be the most suitable for litho print quality. The printing quality is very good because lithography printing technology is used for printing.

2.5 Digital Printing

Digital printing is a relatively new method for packaging applications. In packaging, materials or substrates are chosen because of their strength, barrier, temperature resistance and other physical and chemical properties and are not necessarily to print with traditional printing processes. These substrates are designed in various shapes, styles, sizes and irregular shapes which create a surface hard to print without compromising the physical properties. Digital printing offers a non-impact printing option which can print on labels or directly on to the corrugated board without touching the substrate. Advantages of digital printing make printing easier on non-uniform surfaces without compromising on properties.

Digital printing has very unique advantages in the corrugated industry. In a survey conducted by Packaging Digest where 10,000 packaging producers reported short runs, fast reaction times, prototype, sample printing and prototypes are the main reason for the growth of digital printing technology (Massimo 2010). One of the main advantages of this process is that it can be very economical in short run orders compared to traditional processes. Currently, digital printing is suitable for printing 10 to 500 boxes (Arzoumanian 2011). This advantage can prove a very helpful for small volume POP (Point of Purchase) displays business and other low volume jobs.

The principle of digital printing used for printing corrugated board is inkjet technology. Inkjet is capable of producing both text and images on the corrugated surface. It is a non-impact printing process where no printing master contacts the substrate, only the ink makes contact with the substrate. Artwork to be printed is directly sent to the machine as no printing plate step is required. The artwork file is processed through a RIP (Raster Image Processor) which converts the file into a machine readable format.

Inkjet technology is categorized into two sub groups and is discussed below:

2.5.1 Continuous inkjet

2.5.2 Drop-on-demand inkjet

2.5.1 Continuous Inkjet

In continuous inkjet technology, a continuous stream of ink is injected through a nozzle at high speed which causes the ink to break into small drops. The size of the ink droplets is one of the big factors in output printing resolution and is determined by surface tension of the ink, the pressure applied in injecting the ink and nozzle diameter (Smyth 2002). The placement of the ink in one direction is controlled by magnitude of electrostatic charges and in other direction it is controlled by the movement of inkjet head or substrate (Smyth 2002). In an inkjet head having an array of multiple nozzles, ink droplets are projected directly onto the substrate. Ink in image area sticks to the substrate and ink in non-image area is deflected by the electrostatic charges. Ink is deflected in the guttering and ink recirculation system for reuse. Guttering and ink recirculation system makes the design complex. Due to the continuous stream of ink, the printing speed is fast.

2.5.2 Drop-on-demand inkjet

In the drop-on-demand process, a drop is generated only when ink is demanded for the image. As drop is generated on demand, no guttering and ink recirculation assembly is required making the design simpler than continuous inkjet. The drops can be generated thermally, electrically or by piezoelectric effect.

Piezoelectric inkjet technology is very popular and used more commonly due to its simplest way of drop generation. In a piezoelectric inkjet printer, ink drop generation is a result of change in volume of the ink chamber. The change in volume is triggered by the imaging signal which causes the piezoelectric ceramic to deflect to change the volume of the ink chamber. Changed volume causes the ink ejection out of the ink chamber in the form of droplets through the orifice. When the volume returns to the original state, more ink is introduced to fill the chamber from the reservoir. The ink drops sticks to the substrate and forms the image.

Ink is a mixture of colorant, vehicle and additives. A colorant gives color to the ink. Vehicle acts as a carrier to carry the colorant and additives add specific properties to introduce the required property in the ink such as viscosity. Inkjet printing ink uses two types of colorants – dyes and pigments (Johnson 2005).

Dye color particles are very small and fine in shape. It can dissolve in the vehicle. When an ink is applied on a surface, these fine particles enter below the printing surface and offer a glossy rich color to the print. However, these particles are very susceptible to light fading. Pigment colorants are crystalline solids which are much bigger in size as compared to dye molecules. Pigment particles do not dissolve in the vehicle and remain in a dispersed state. Due to the big size of the pigment particles, it offers less surface area for light to react and is less light sensitive to light fastness compared to dye colorants. However, big particle size causes more light to scatter and hence reduce the color gamut.

One great feature of digital inkjet printing is that it needs no plate for printing, which makes for a very fast set up time with no upfront cost to the customer. The quality of digital inkjet printing is lower than lithographic and higher than flexographic printing (Barnes 2011). Some of popular digital inkjet printing machines currently serving the corrugated industry are HP (Hewlett Packard) Scitex FB 6700, Omnia 2500, Rho 750 HS and Sun's CorrStream. These machines are developed by HP, Omnia, Rho and Sun companies respectively. Advancement lies in the print head of the machine, the more advanced and better the print head, the higher the quality and speed will be. For example, HP Scitex FB 7500 uses a print head with 39,939 nozzles and a 20kHz firing frequency which results a high quality image at high speed than normal (Future, 2010). Multiple nozzles are installed in the print head. Depending upon the configuration of the machine, multiples colors can be produces using one print head. Certain numbers of nozzles are dedicated for a particular color enable multi-color printing in one pass.

Other than corrugated boxes, digital inkjet printing is used for printing folding cartons, books, magazines, greeting cards and other where low volume and customization is a requirement. Litho-labels can also be printed with digital inkjet printing for a short run job.

However, there are some limitations to the digital inkjet printing which includes:

1. Slow printing speed
2. Smaller color gamut
3. Expensive ink

As mentioned above, the advancement of the printing head is one of the reasons for the slow printing speed. Digital inkjet printing works on the principle of scanning technology. In scanning technology print head prints the sheet in a scan mode which is a slower process than a rotary process. Due to above mentioned limitations, digital inkjet printing is yet to gain popularity in the corrugated industry. Die-cutting is the subsequent step after printing.

2.6 Die-Cutting

Die-cutting is one of the post-printing processes. Once the printing is done, the next step in box making is to crease and cut the box blank. Paperboard is processed through a die-cutter in order to get the desired box style shape. Die-cutter is a machine which uses a cutting dies to crease and the cut the box blank in a desired style and shape.

A die is flat or curved plywood surface, generally, embedded with two types of steel rule: the cutting and creasing rules. Creasing rules have a function of putting crease on the box. It has a top round which crushes the flutes of the box and creates a crease so that a box can fold easily. The cutting rules have sharp edge which cuts through the box blank and separates the unwanted area of the blank. On the adjacent side of rules, a closed cell rubber strip is glued which acts as the ejection rubber. The rubber strip is greater in height than the creasing and cutting rule. When die cuts the blank, the pressure from the rubber keeps the scrap away from the die. For special purposes, special kind of rules can be added on the plywood surface of die such as perforation rules.

Depending upon the shape of the plywood surface, die-cutters can be categorized into two types:

2.6.1 Flatbed Die-Cutter

2.6.2 Rotary Die-Cutter

2.6.1 Flatbed Die-Cutter

As the name suggests, it is made on a flat plywood die. The shape of the box is incised in the plywood by using a laser or a saw. Creasing and cutting rules are then cut to the required length and fixed into the plywood surface. Die-cutting is performed by pressing the die against the blank. Pressure from the mechanically assisted die process the blank and a die-cut finished piece is received at the delivery side.

Flatbed die-cutting is a simple process used to process complex shapes where great detail and accuracy is required, such as point of purchase displays. However the speed is slower than the rotary die-cutter.

2.6.2 Rotary Die-Cutter

Rotary die-cutters are high speed die-cutting machines and normally used for higher volume jobs. The die is made up of a curved plywood surface concentric with the die mounting cylinder. Creasing and cutting steel rules are also curved in shape so that it can be properly embedded in the plywood surface. Nip pressure is provided by a supporting cylinder running along with the die mounting cylinder.

Rotary die-cutters are generally installed in-line with a flexo-folder gluer machine however flatbed die-cutter is usually a separate machine and process the litho-labeling and litho-lamination box blanks.

In the die-cutting section, die cost is an upfront cost to the customer. Just like printing plates, a customer has to pay for the dies as well.

Chapter 3

Costing Basics

The crucial step in the research is to determine the primary cost drivers for four different types of printing options: flexo post-print, flexo pre-print, litho-lamination and litho-labeling. Flexo pre-print is not included in the research as it was understood from the personal interview of professionals in the industry that since it is only used for extremely long runs, it is outside the focus for this research on low volume applications. This section describes the traditional printing cost estimation and the basics related to costing of these printing options.

3.1 Basics of Costing for Different Printing Techniques

Before determining product costs, it is important to understand the unit of analysis for making the cost determination. The unit of analysis is referred to as "cost object". A cost object is the product or service for which cost analysis is done. In this project, the cost object is a 10" x 10" x10" RSC (Regular Slotted Container) corrugated box (hereafter referred to as "box"). The analysis will study the cost of printing of this box using the three different printing processes.

Some costs of product can be directly identified to each box. These costs are referred to as "direct" costs. The direct costs for a box include the materials used in making the box i.e. paperboard, dies, inks and printing plates. Direct costs are easy to trace and allocate.

Some costs cannot be directly identified to a cost object because they are shared amongst various other box types and customer types. These costs are referred to as "indirect" costs and require efforts to trace it. Indirect costs for a box include costs such as facility administration, building rent, electricity, machine depreciation, machine set-up, manufacturing labor, production supervisor, fork lift truck, and sales team costs. Indirect cost items serve multiple jobs and hence a part of indirect cost is allocated to each cost object in order to obtain an accurate assessment.

Indirect costs are pooled into homogeneous cost pools and allocated to the box using a cost allocation basis (such as direct labor cost, material cost, machine hours, etc.).

3.2 Costing Method and Cost Hierarchies

Cost flows are the result of process flows. Therefore, to get an understanding of costs, it is important to understand process flows. For example, the litho-lamination process can be broken down into the following list of activities related to the flow of processes:

a. Single face corrugated board is produced on a corrugator machine.
b. Raw materials such as paper board and ink are fed into the litho printing machine for printing top liner sheets.
c. The printed sheets move to the litho-lamination machine where they get married to the single face corrugated sheets and come out as semi-finished product.
d. The semi-finished boxes go through the die-cutting and finishing process.
e. The finished boxes are then packed and transported to the warehouse.
f. The boxes are shipped to the customer from the warehouse.

In addition, administrative processes occur such as receiving customer orders, making invoices, and obtaining payments. There also has to be administrative staff involved in accounting, HR (human resource), legal, and supervision, whose costs have to be allocated to the boxes.

The following illustrations show a graphical view of process flows and cost flow for all four traditional printing processes. Each figure shows the machine used in the process, flow of production, variable cost flow, fixed cost flows, batch level and unit level costs.

Flexo Post-Sheet

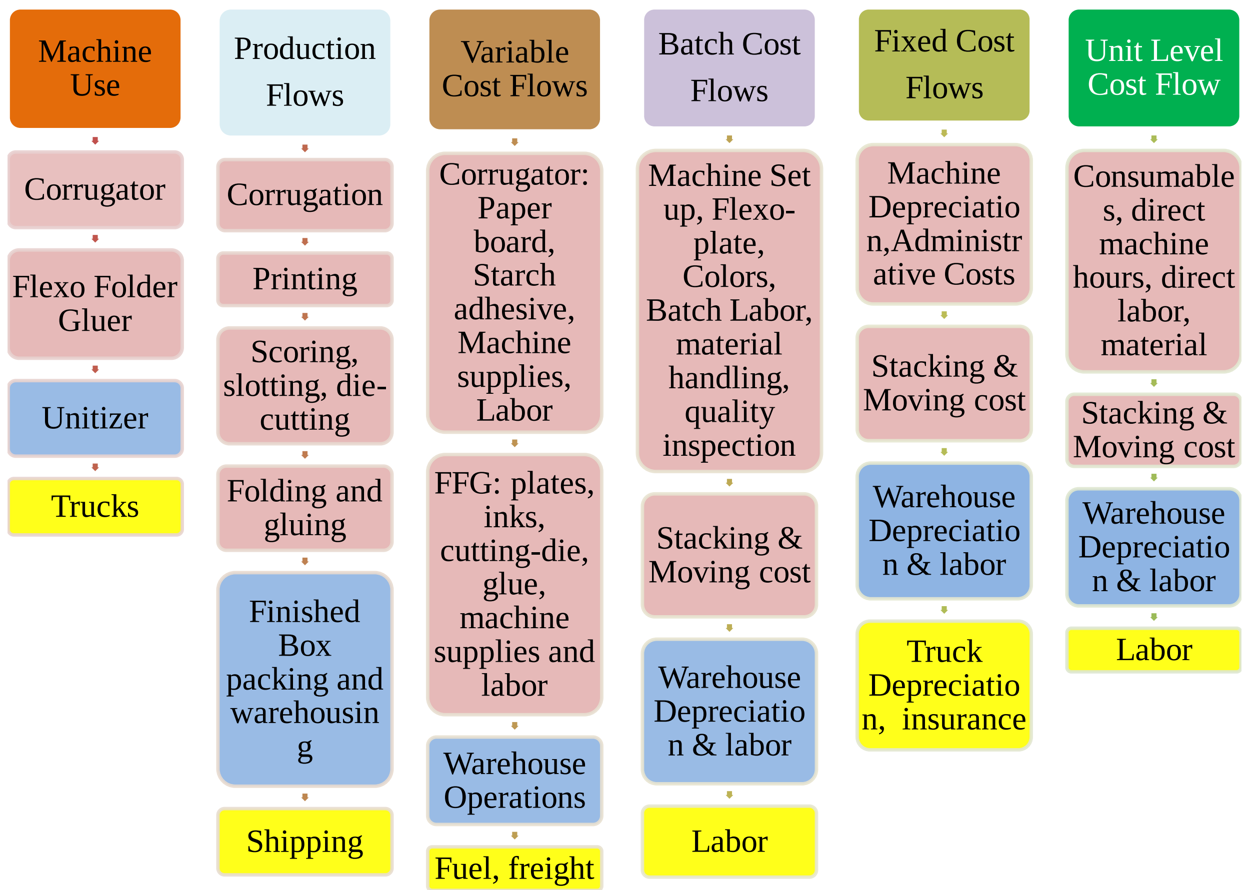

Figure 3: Flow of operations for flexo post-sheet (For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis)

Flexo Pre-print

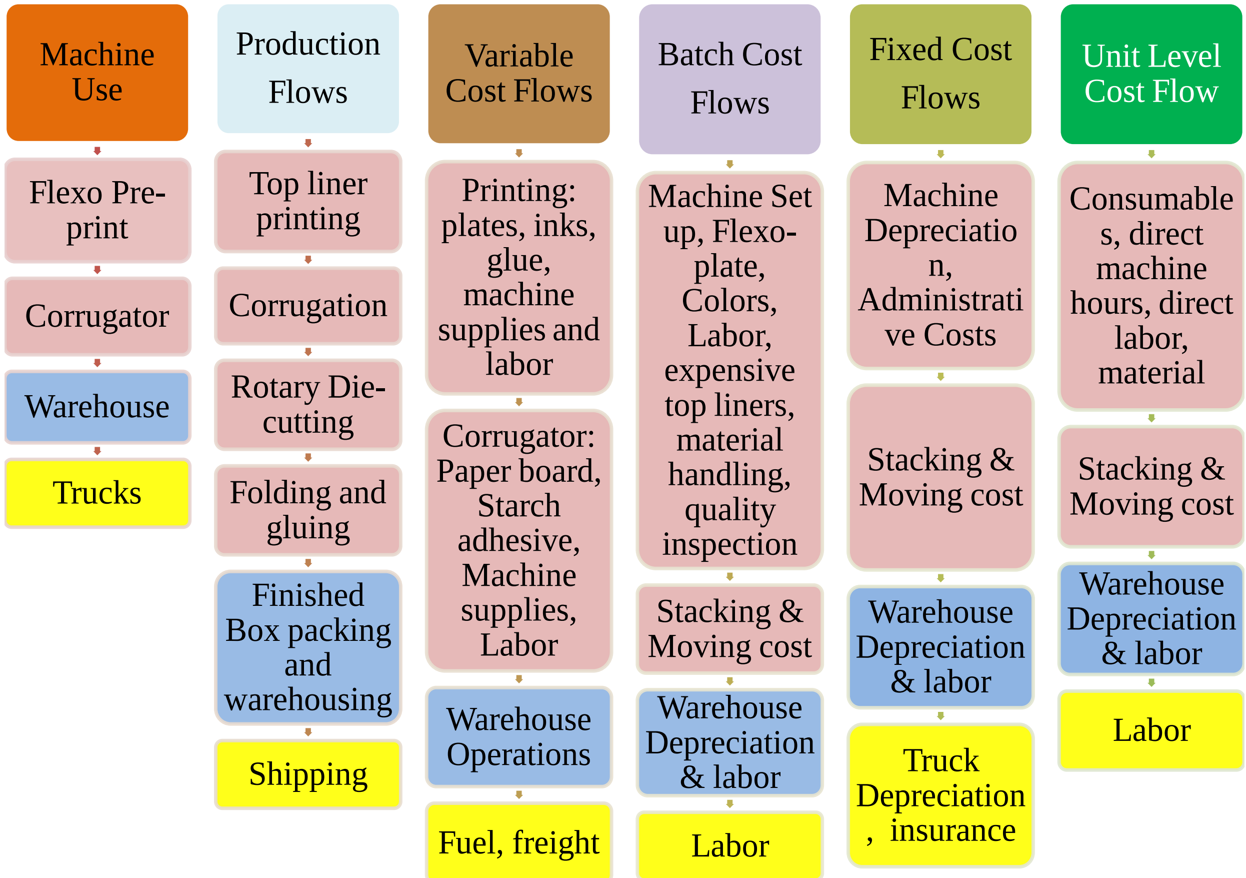

Figure 4: Flow of operations for flexo pre-print

Litho-lamination

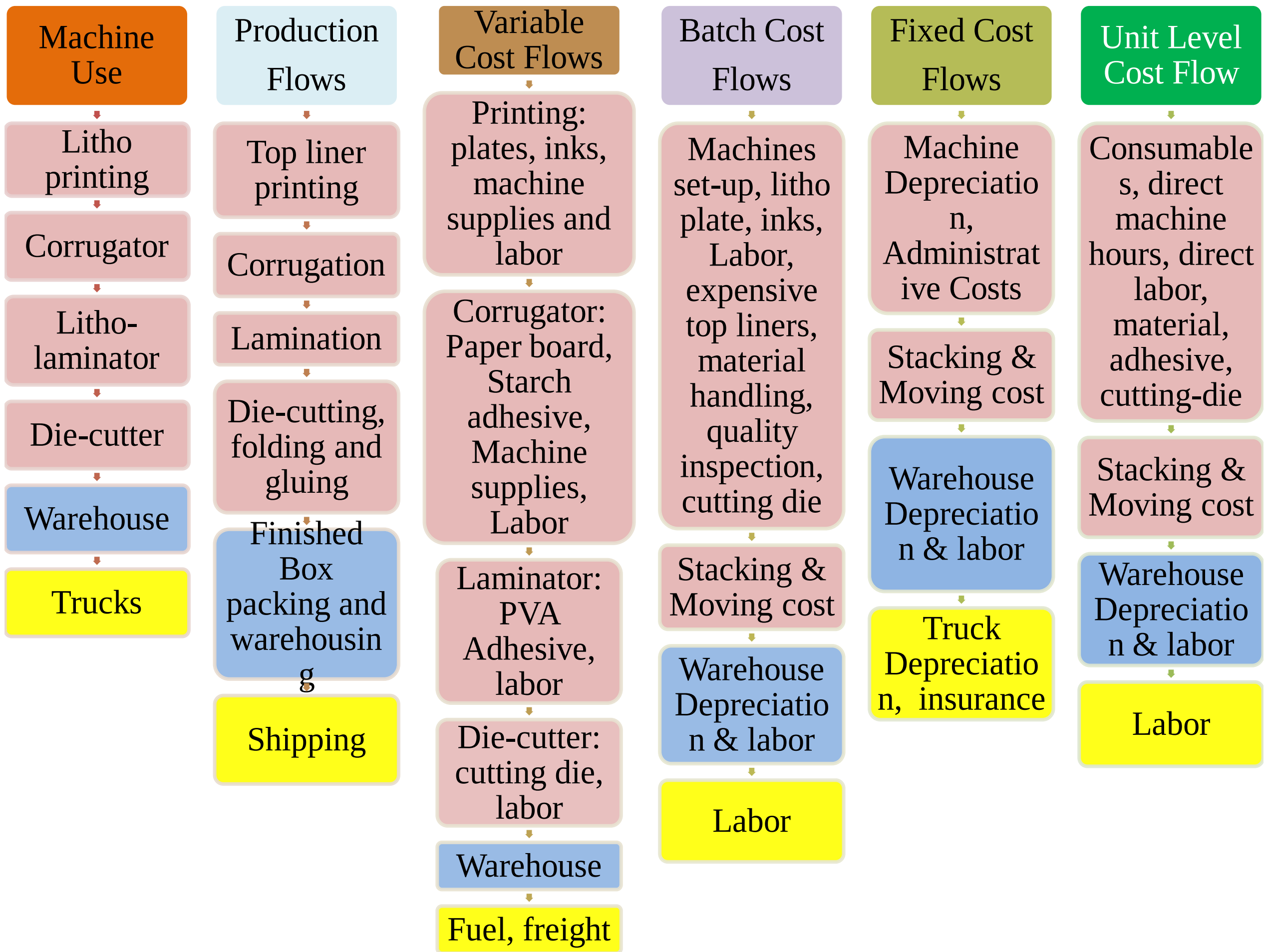

Figure 5: Flow of operations for litho-lamination

Litho-labeling

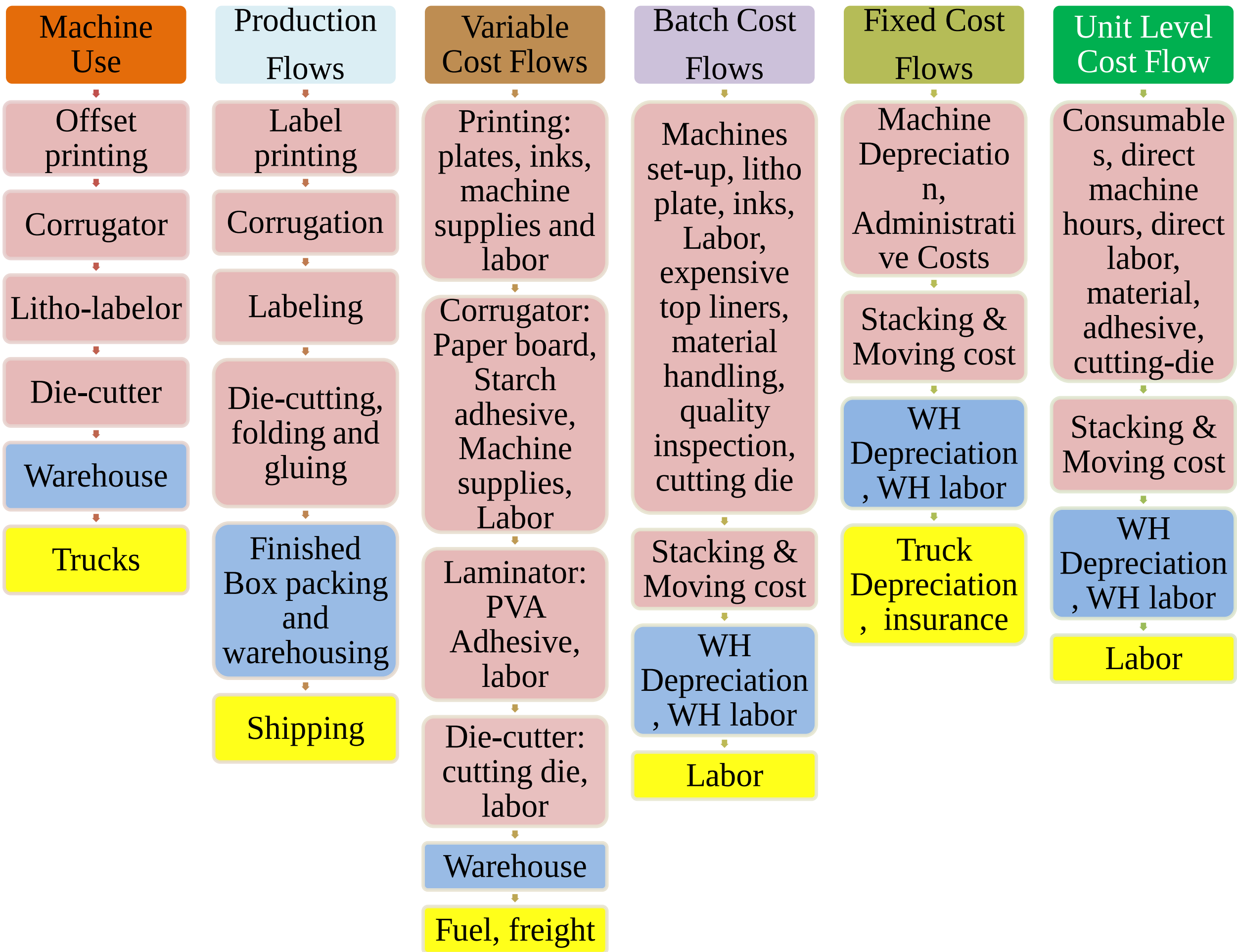

Figure 6: Flow of operations for litho-labeling

Various fixed and variable are associated with each of the process. Fixed cost does not depend upon the volume of a job. These costs stay fixed and do not change with the number of jobs and volume of job. For example, rent of manufacturing facility is fixed and does not depend upon the quantities produced inside the plant. On the other hand, variable costs depend upon the number of job and volume of job. Variable costs vary with the quantity produced inside the plant. For example, paperboard is a variable cost. Total paperboard cost increases with the number of boxes produced.

Various costs are therefore incurred during a traditional printing process. For example, the litho-lamination process, direct costs include paper board, adhesives, ink, dies, paper scrap and wastage. Indirect costs include machine operations, depreciation, factory administration, electricity, supervision, fork lift and manufacturing labor. These costs are allocated to the box using appropriate cost allocation bases, which can differ amongst companies and is decided by the top management.

The objective of the cost allocation base is that it should be associated with the resource usage, i.e., a box should be allocated to the amount of overhead that corresponds to the usage of the overhead resource. For example, suppose machine hours are associated with the amount of resource use for the machine related overhead. If the machine hour rate is $100/hr (which is derived by taking total machine related overhead and dividing by total machine hours used) and a job requires two hour of finishing, a total of $200 cost of machine related overhead should be allocated to it.

Overhead costs can be further classified into various categories that differ based on the level of aggregation. For example, some cost drivers can be related to each **unit of output** and are mainly volume driven. Examples of costs in this category are consumables and supplies. As the production volume increases, consumable consumption will increase and correspondingly, the total cost will also increase. These costs can be traced per unit of output for example, cost/box. Similarly, direct machine hours and machine operational cost will also increase with volume of output, although they cannot be traced to each unit. Hence, output level overhead costs are volume dependent unlike batch level costs which are batch dependent and discussed in the next paragraph.

Some costs arise at the level of each batch and are referred to as **batch-level costs**. These costs are primarily driven by the activity related to batch production runs Horngrn T. Charles, Datar M. Srikant and Rajan Madhav 2011). Examples of costs in this category are set-up cost (which can be allocated to the boxes based on set-up time), shipping cost (which can be allocated based on shipping batch size), material handling cost (which is based on the number of production runs), and quality inspection (which is associated with number of batches). Set-up time is not fully dependent on volume but rather depends on the complexity of the job and on the size of the batches. For example, if a job requires changing a color, the whole print station needs to be cleaned thoroughly to avoid mixing of previous color. As opposed to this, jobs that do not require color change and hence do not require as much cleaning and set-up time. As the new batch or a new job comes into production, the whole machine setting may need to change, which consume time and cost. These costs vary at the level of the batch rather than on the unit.

Some costs can be identified at the level of the **product line** rather than to the unit or batch of boxes. For example, POP displays require a different set of processes. Some overhead costs can be identified to only POP displays rather than for boxes. An example of this cost would be die-cutting machines that are only used for making POP displays. These costs can be identified to the POP product line and then allocated to each POP unit based on an appropriate allocation method such as complexity of display (number of joints for example).

Overhead costs can also arise at the level of the **customer**. Examples of this cost would be ordering and sales management, transportation, prototypes, and customer relationship management. These costs can be identified as occurring for one type of customer compared to another; therefore they can be traced to the level of the customer. Subsequently, they can be allocated to the units that are attributable to the particular customer.

The highest level of aggregation occurs in the case of **facility-level** costs such as administration and support expenses like accounting and HR. These costs are typically allocated to products based on a cost driver such as number of personnel employed or square foot of space occupied.

3.3 Printing Cost Estimate

This chapter describes how costs are estimated in the printing industry. Cost estimating method follows a step approach. Each step involved in cost estimation is discussed as follows:

3.3.1 Production planning

It is the first step in cost estimation process. In production planning, an estimator plans the production process depending upon the job requirements. Estimator divides the job into production steps which all combined together reflects the manufactured product. A print job can involve various different steps some of which may drive by the customer requirements. For example, a customer may request for a pantone color printing or a special security feature in the printing. Print area, substrate, number of color, printing method, size of machine, speed of machine and quality are some of the factors which can lead to variations different steps in a printing job. The estimator, based on the company's production capability and economics, decides which part of the production is most economically to produce inside the printing plant and which is more economically to print outside the company. This stage is important because as many costs get locked in at this stage. Once production planning is completed, the second step is to estimate costs.

3.3.2 Assigning Cost

In the cost estimation process, an estimator carefully assigns production time and hourly cost to each production step depending upon the set-up time and volume. The hourly cost is called BHR (budgeted hourly rates) (Ruggles 2008). It is easy to assign BHR to in-house production steps but very hard to do so with off-house production. The cost to off-house production segments are called buyouts or outside purchases and added to the total cost of the internal production (Ruggles 2008).

The estimator also calculates the cost of total material or direct costs used in the production. It includes raw materials like substrate, inks, printing plates and cutting dies. These costs are called material cost or direct cost and can be directly traced to each specific job.

After calculating the direct cost, estimator calculates the indirect cost. Indirect cost cannot be directly traced to each specific job and are assigned using standard production time and predetermined BHR.

Standard production times are defined as the average production output per unit of time. It can be calculated in many different ways such as sheets per hour, foots per minute and hours/1000 impressions (Ruggles 2008). As the production rate can vary depending upon the skill of an operator and other parameters, averages are used to closely predict the output of a machine under normal operating conditions.

Indirect costs are calculated by the multiplication of standard production time and BHR of that machine. For example, if a BHR of a machine is $100/hr and runs for 2 hours, the indirect cost would be $100/hr x 2 hours = $200.

Total cost includes sum of direct cost, indirect cost and buyouts. To get the estimated cost of a job, the following equation is used:

(Standard production time X *BHR) + Material Costs + Buyout Costs = Estimated cost to a* job

Estimated cost does not include profit. In order to establish a selling price, profit is added to the estimated cost. Profit can vary from company to company and volume is another big reason for change in profit. Bulk order gets more discounts and profits are less however the total revenue is higher and hence the total profit is higher.

Overhead costs are usually complex to assign to the jobs. The following section provides additional detail about major overhead cost pools in printing. The first major item of overhead is machine cost. In the printing industry complex and expensive machineries are used. Machines can be fully automatic which are high speed machines and can be semi-automatic or manual which are low cost machines and has a comparatively slower speed of production.

The second major item of overhead is labor. Skilled operators are required to operate the printing machines. Skilled operators are capable of optimally running the machine. They can ensure smooth operation in order to produce a good yield and quality job.

Another major category of cost is set-up cost. For example, to set up a lithography printing machine to ready for a job, operator has to load the paper and set the feeding station. The operator has to check the ink levels, add the fountain solution in the dampening unit, mount the printing plate, clean the blanket and set the delivery station. In addition, the operator also has to run some preliminary run to set up the nip pressure to make sure machine is ready to produce a quality job. For example, all the activities takes an operator 0.20 hours (0.20x60 = 12 minutes), this represent the average time to perform these activities or in estimator language set-up time of the machine.

The Budgeted Hourly Rate is the total indirect costs of a cost center and divided by hours of production. The example above shows the setup of a standard production time for a number of activities in a cost center. But this cost center also includes paper and ink waste which were used to set up the machine. If the BHR for the press is $200/hours, the machine set up cost will be 0.20X200 = $40 and if we add $15 for the paper and ink, the set up cost for the machine would be 40 + 15 = $55.

Standard production time multiplied by BHR gives the estimated cost of a cost center for a particular job. It can be seen from the above that total cost is sensitive to the BHR (budgeted hourly rate), therefore the BHR has to calculated carefully and accurately. It will ensure that the amount charged to the customer is in accordance with the actual cost involved in the production. Using an incorrect BHR can have serious consequences. A customer can be over charged or undercharged. If the customer is overcharged, the firm can lose customers to competitors and on the other hand undercharging can reduce the profits with negative consequences for the company.

3.4 Estimating Direct Cost

This section describes the method to calculate the direct cost involved in a printing job. As mentioned earlier, direct cost involves material directly used in the production of the box. These materials are discussed as follows:

3.4.1 Paper

3.4.2 Ink

3.4.3 Cutting-dies

3.4.4 Pre-press and Printing Plates

3.4.1 Paper

Based on data from corrugated companies, material cost accounts for 70% of the total cost of any print order and paper is the most used material (Barnes 2011). Generally a variety of substrates are used in the corrugated and printing industry for making boxes. The most common type of paper for corrugated boxes is unbleached brown kraft paper. The process of selection of the appropriate paper depends upon the paper parameters and is discussed below:

i) **Paper thickness**: It is the thickness of paper. During the manufacturing of the paper, the amount fiber deposit on the screen determines the paper thickness. It is also called paper caliper. It is measured in points, expressed as pt. and 1 point is equals to 0.001in. Generally, printed sheets for litho-lamination are thick board like SBS and can have thickness such as 16 pt.

ii) **Paper Size**: Depending upon the type of paper, different paper sizes are available. For example, business paper comes in a basic size of 17x22in. However, custom sizes can be created on special request if the amount of paper required justifies the customization economics.

In case of corrugated boxes, required size of corrugated blank is cut directly on the corrugated machines after the corrugation process. Generally, corrugation machine run with a higher width kraft paper roll and produces two or three jobs simultaneously depending upon the size of the individual job. The width of the kraft paper roll will depend upon the size of the machine.

ii) **Basis Weight**: It is the most common way of expressing paper weight. As the prices of paper are expressed in dollars/ton, so it is the basis for pricing paper based on weight. In the USA, basis weight of a paper is expressed as the weight in pounds of a ream of 24”x36” size of 500 sheets as a total area of 3000ft^2. Similarly, basis weight for paperboard is expressed as the weight in pounds of a ream of 12”x24” size of 500 sheets as a total of 1000ft^2 (Twede, Selke 2005). It is represented as BW.

Paper is a commodity and therefore prices are well established by the market. Paper manufacturers provide catalogs to printing estimators who use it to estimate the paper cost based on the basis weight, size, thickness and quantity required by the customer. Most catalogs list the price in CWT (hundred weight or centum weight) i.e. price per 100 pound. Paper merchants convert CWT price to price per 1000 (M) and arrive at price per sheet rather than price based on weight. There are two simple formulas to determine M and CMT prices.

M Sheet price = (CWT price / 100) x poundage per M sheet

CWT price = (M sheet price / poundage per M sheet) X 100

3.4.2 Ink

As mentioned earlier, paper is the most expensive material in any print order. Ink is also an important material however it usually accounts for 2% to 5% of the total cost of a print order. It is important to accurately estimate the amount of ink used because if this estimate is not accurate, it can reduce profit margins.

Ink quantities are estimated using ink mileage charts. These provide the approximate number of thousand square inches of area covered by one pound of ink (Ruggles 2008).

A number of variables need to be considered while estimating ink consumption. These include type of substrate, substrate smoothness, color and type of ink. Paper smoothness affects ink consumption as smoother the paper surface, lesser the ink required. For example a coated paper will require less ink than an uncoated paper. Color and type of ink are the other factor that affects the ink performance. Dark color give better ink mileage than lighter inks and transparent ink runs more than opaque inks.

Ink coverage is a factor that plays an important role in estimating ink cost. It is the amount of area on a substrate where ink will be printed and expressed in percentage. A greater ink coverage area requires more ink and vice versa. For example, a 50% ink coverage job will cover the half of the page with ink.

Waste ink should also be included in the ink cost estimation. Ink can get wasted in many different ways such as poor storage of inks, left over ink on the machine, ink roller cleaning and residual ink in the container. Generally, the total amount of ink wastage is about 10% of the total ink for the job.

As above mentioned factors affecting ink estimation and hence there is a formula that account for these factors to get the approximate ink estimation (Ruggles 2008).

Weight of ink (lb) = (total print area X percentage ink coverage X total no. of prints X anticipated ink wastage percentage) / ink mileage factor

In the end, weight of ink is multiplied by the price of the ink which is generally $/lb to get the ink price.

3.4.3 Cutting-Dies

As mentioned earlier in section 2.6, a cutting-die is a tool made of plywood and steel rules use to score, slot and cut features such as hand-holes in the box. Toe types of cutting-dies were discussed flat cutting-dies and rotary cutting-dies.

A cutting-die cost can vary a lot depending upon the type of die, size and complexity of the job. Rotary cutting-die costs more than flat ones. These are mostly purchased from a third party specializes in manufacturing dies. Dies costs are added directly to cost estimate as a buyout. Cutting-die cost is a fixed direct cost and does not changes with the volume of the job. It can be changed if the volume is too large or time sensitive jobs where more than one cutting–die is required. For a reoccurring job, cutting-dies are stored for a later use.

3.4.4 Pre-press and Printing Plates

In order to create a printing plate, an artwork is created which represents the image to be printed on the box. An artwork creation is a prepress operation. Electronic prepress, generally called “prepress”, is the first part of any print job. In prepress, content creation, graphic designing, image development, film making, proofing, platemaking, correcting customer files etc. is done. Prepress creates some kind of output for the press section such as printing plates for the lithography or flexography and print ready files for digital printing.

Content creation usually starts with graphic designer understanding the customer requirement. The process follows following steps - thumbnail sketches, rough art renditions, comprehensive work and finished artwork respectively. Thumbnails and rough art renditions are generally created by hand or sometimes digitally. A number of sketches are created depending upon the customer needs and as it flows thorough these four steps only very limited number of designs left at the stage of final artwork. The final artwork is then converted into digital format for further processing.

A number of computer hardware and softwares are required in the prepress operations. Hardware includes computers largely Macintosh, printers, scanners, digitizing tablets, plotters, high resolution screens with dedicated graphic cards, magnetic drives for data transfers, LAN for connectivity to other computers etc. Softwares may include Adobe Creative suite softwares such as Illustrator, Photoshop, InDesign, GoLive and Adobe PageMaker and other softwares like Corel Draw, Mac iPhoto, QuarkXpress, Dreamweaver and Flash.

The prepress production can be divided into two production functions: imaging production and output production. Imaging production can be divided into five activity groups which are Job setup and preliminary activities, text processing, image creation, image processing and image manipulation. Depending upon which activities are used, total time of each activity is calculated and summed up to get the total time for image production. A BHR is generated for image production which includes computer platform, softwares, labor, space and other fixed and variables cost. Multiplication of BHR and time gives the cost of image production.

Output production can be segmented into Laser output (output from a printer), digital proof (output from a plotter or a proofing machine), and filmsetter/CTP output. Laser output is a fast and economical way of producing output. It is just a printout from a color printer. Digital proof is used to produce jobs where color matching is critical. All machines are calibrated and color management systems are implemented to match colors. Lastly, output can be in the form of film which is used to make plates or can be on the plate directly which is called computer to plate (CTP). Total cost of output production is calculated the same way as image production. Total time used in the process is multiplied by the BHR of the machines used to get the cost of production. Material cost is separately added to get the total cost.

In most cases, a printing plate is considered as the output of the prepress. CTP is the most common method to get the plate output for lithography. For flexography, a film negative of the artwork is created using an imagesetter. The film negative defined the image on the plate. Artwork can be sent to the laser machine which engraves the image on the plate. A BHR is developed for the CTP machine or laser engraving which is multiplied to the total time to get the total plate making cost. CTP plates can cost around $500 for 4 color printing plates for lithography (Barnes 2011). The material used in flexo printing plates is expensive than the material used in litho plates and hence Flexo plates are expensive than litho printing plates. Flexo plates can cost around $2,500-$4,000 (Barnes 2011) for flexo post-sheet and around $12,000 for a flexo preprint job in four colors (ICPF 2011).

Chapter 4

Research Method

The three primary goals of this research project are:

- To identify the major cost drivers for the three printing techniques, i.e. flexo post-print, litho-lamination and litho-labeling.
- To provide a basis for comparison of the cost of digital printing relative to the traditional printing techniques with emphasis on low volume printing.
- To estimate the cost of a four color printed standard (10” x 10” x 10” RSC) box using these three alternate techniques at different levels of output.

The following section describes the method used to estimate the cost of producing a printed corrugated box using the traditional processes. Total cost calculated is sum of direct cost, indirect cost, profit and buyouts.

Direct Cost Tracing: As mentioned in Section 3.3, direct costs are specific to a cost object, i.e., they can be identified to the specific cost object and is not shared amongst cost objects. Direct costs are traced to cost objects.

- Paperboard materials directly used to make an output
- Printing plates
- Ink
- Cutting-dies
- Buyouts

Identifying indirect cost pools: Indirect costs are costs of a resource used by more than one cost object. Indirect costs are allocated to cost objects and include for example:

- Machine is used to make several types of products

- Building is used by several departments
- Labor directly used to make an output (touch labor)
- Metered utilities that are used by a customized output
- Service department that provide services to multiple departments
- Transportation, contracting
- Facility Administration, Parking, security

4.1 Method

The cost of producing a standard box is compared for four printing methods. A 10” x 10” x 10” RSC box is compared in eight different quantity breaks: 1; 10; 50; 100; 500; 1,500; 20,000 and 100,000. The size of box was chosen based on advice of professionals in the industry, as a representative standard for comparing costs. The quantity figures came from the same source, and based on the minimum order quantity for a particular process. For example, 1 is the minimum number required to economically produce a box with digital process. Similarly, 500 represent the minimum quantity for litho-labeling and 1500 for litho-lamination. However if the company is a high volume box manufacturer, 20,000 is the minimum order quantity for litho-lamination. Flexo pre-print generally requires much higher volume and 200,000 units is a standard minimum order size (ICPF 2011).

Based on field visits and conversation with industry representatives, it was learned that ERP (Enterprise Resource Planning) software systems are available in the market for the corrugated container industry. These powerful software systems are capable of connecting departments in a company such as sales, finance, purchasing, quality, warehouse and logistics and also capable of cost estimation work. The industry standard, Amtech Imaginera, was chosen as having the best available costing tool. The history of these ERP systems for corrugated container industry and the Amtech Imaginera system are discussed next.

4.1.2 Corrugated Industry ERP Systems

4.1.3 Amtech Imaginera System

4.1.1 Corrugated Industry ERP Systems

Elliot Rohde Associates Inc. of Elliot S Rohde, is one of the original companies that developed the first freight, materials and machinery costing standards for these ERP software. Jan Rohde who graduated from the State University of New York at Albany in 1972 with a B.S. in mathematics joined Elliot Rohde and Associates worked there for three years. After quitting, he joined HRMS Inc. (Harry Rohde Management Systems) founded by Harry Rohde. HRMS Inc. provided one of the original software of this kind for corrugated container industry. The company designed and offered business software solutions for packaging manufacturing companies. The software was used for other applications which include folding cartons, retail displays, food and beverage packaging, labels, and multi-wall bags. The company's products include management information systems; software solutions for estimating, payroll, and order entry applications. In 2005, Harry Rohde sold his company to Vantage point systems.

In 1991, Jan Rohde collaborated with his cousin Steve Rohde and started Zytek. Using state-of-the-art technology, Zytek developed a software system which was used in corrugated container industry and folding carton industry. In 2001, Amtech purchased their company Zytek based of Irvine, California (Amtech purchases Zytek 2001). During its span of ten 10 years, Zytek installed its software in more than 150 box plants across North America. The name of Zytek was changed to Sonoma Systems, LLC. After purchase, Amtech enhanced its e-module system to work in conjunction with Zytek software.

In 2004, Amtech acquired Hyperware software company (Amtech Acquires Hyperware 2004). Hyperware product BoxPro was installed in more than 65 corrugated container plans across North America. By that time Amtech family of companies had installed its product into more than 650 box companies and 25,000 users (Amtech Acquires Hyperware 2004). After all the merger, Amtech installed more software in many box plants such as Sisco Box, Safeway Packaging, Apple Corrugated Packaging Inc.; Boxes Inc.; Pax Corrugated Products Inc.; American Packaging Corporation, Innerpac Inc,; Carolina Containers Company and many more. Currently, Amtech product is installed in more than 800 plants and more than 30,000 users (DeNicola 2011). Amtech has become the fastest-growing software company in the packaging industry.

Amtech software appeared to be one of the primary methods for costing in the corrugated printing industry. The Amtech software was therefore used to arrive at dollar estimates of cost for each type of print process. The Amtech Imaginera is described in greater detail next.

4.1.2 Amtech Imaginera System

Amtech Imaginera is an ERP (Enterprise Resource Planning) software system specifically designed for box manufacturing plants for over the past 30 years. The great advantage of Amtech software is that it is Windows based software unlike others which are UNIX based. The software consists of a customer service module, production module and administrative module. The customer service is further categorized in different modules such as cost estimating, CAD interface, quoting, order entry, factory tickets etc. (DeNicola 2004). This research focuses on the job costing feature and uses the cost estimating module. The feature has the ability to measure all primary and secondary cost accurately which assures the accountability of all the cost elements to provide a better cost estimation for the purpose of bidding on the job.

Currently, the Amtech is the leading software for costing and pricing in the corrugated packaging industry. The software has a market share of 60% (DeNicola 2011). Values based on data aggregated over many companies were pre-loaded for us by Amtech and therefore can provide an accurate view of costs.

Figure 7 shows the user interface screen of the software. In the maintenance tab, links can be found to enter all the raw data for cost estimation. For example, ink costs can be entered in the "Ink Cost" tab located under maintenance tab. Similarly, paperboard costs, buyout costs, additional material costs, type of machines and number of operators can be entered into the software. Number of quantities to be produced can be entered into customer service tab and final costs can be calculated in the same tab.

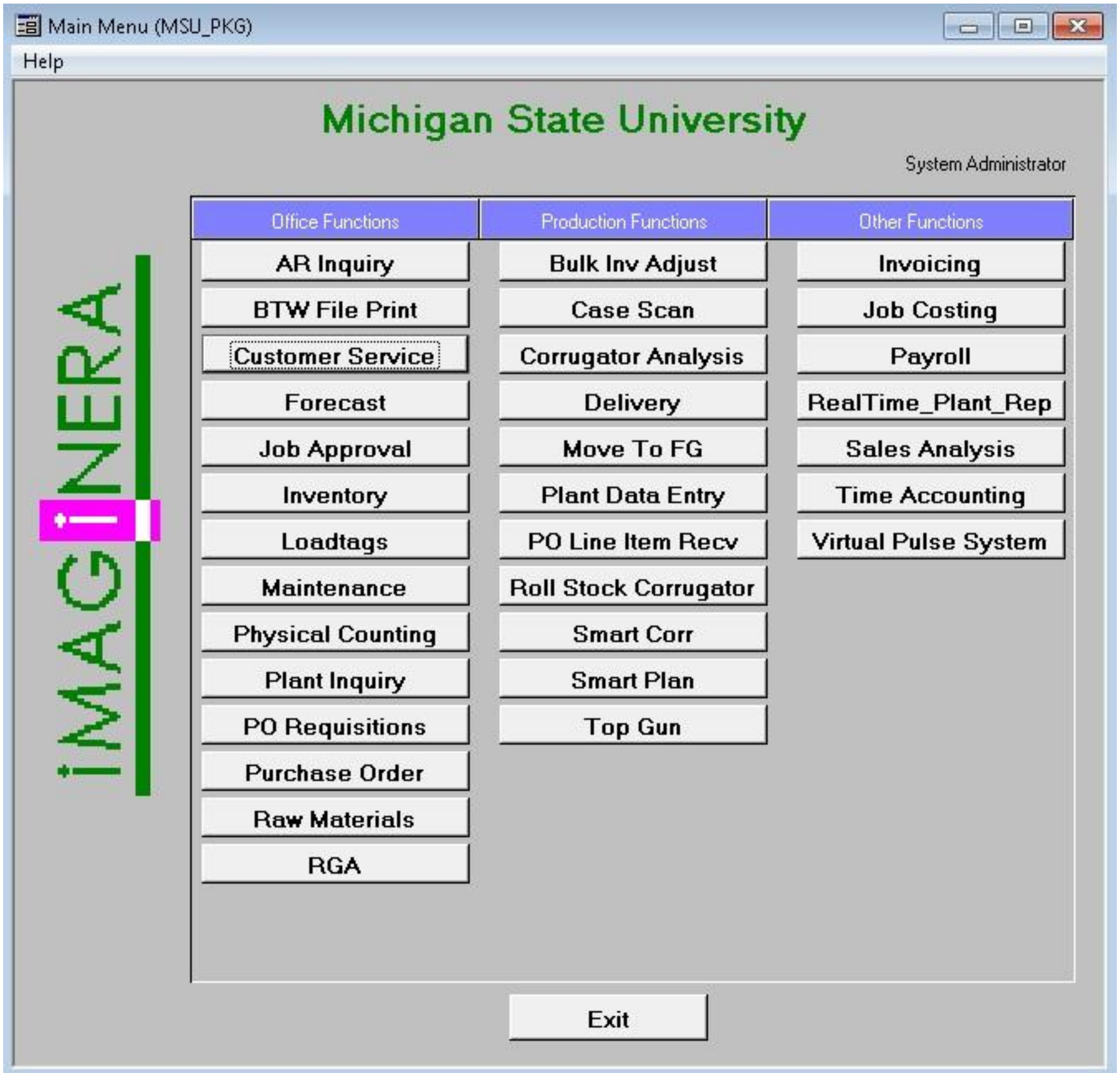

Figure 7: User Interface of Amtech Software

4.2 Cost Assumptions

This section provides details about the cost assumptions used by the Amtech software for each major category of cost. The price of 200-B flute corrugated board is the price per MSF of the combined board which includes all board manufacturing costs (Barnes 2011). B-flute offers the minimum flute height among A-flute, B-flute and C-flute and provides a better printing surface comparatively.

4.2.1 Paperboard:

Table 1 below summarizes the cost of 200 B-flute corrugated board loaded into the software for cost estimation. Cost depends upon the volume of board. Two different columns show different corrugated cost for flexo post-print & litho-labeling and litho-lamination. Litho-lamination uses two plies of paper whereas other method uses three plies of paper and hence costs are different.

Upto MSF	$/MSF (FFG & Litho-labeling)	$/MSF (Litho-lamination)
3	65.00	55.00
12	57.00	47.00
111	53.00	43.00
584	50.00	40.00

Table 1: Price Break of 200-B corrugated board (Source of Corrugated Board Cost: Michigan Packaging Company)

4.2.2 Ink

Table 2 summarizes the ink cost used for flexo post-sheet process. No lithographic printing ink costs were entered into the software because litho printed sheets were directly purchased from third party supplier and hence added as buyouts in the cost. 100% coverage area is used for printing purposes.

Ink Description	Cost/MSF @ 100%Coverage ($)	Cost/lb ($)
Black 90	0.90	2.70
Red 30	1.00	3.00
Process Cyan	36.00	12.00
Process Magenta	36.00	12.00
Process Yellow	36.00	12.00
Process Black	36.00	12.00

Table 2: Ink Costs (Source of Ink Cost: Landaal Packaging)

4.2.3 Additional Materials and Transportation

High cube container is used for shipping from warehouse to customer. The dimensions for container are 45'x 94" x 102". The container is more efficient in terms of cost compared to standard 40' containers. The costs of additional material are described in the table 3 below:

Material	**Price Description**
Pallet	$5/pallet
Label Glue	$5/MSQ
Unit Strap	$0.15/MSQ
Bundle Strap	$0.08/MSQ
Bleached Outside (Optional add-on)	$13/MSQ
Bleached Inside (Optional add-on)	$13/MSQ

Table 3: Additional material and price description (Source of Cost: Amtech Imaginera Software)

Chapter 5

Results

This chapter provides the results of estimating the cost of a box as a function of the printing method used, number of colors printed, and the size of the order. Section 5.1 provides the results for different run lengths for each printing process evaluated. Section 5.2 summarizes the major drivers of cost and discusses sensitivity of product cost to these drivers.

5.1 Run Length Results

Using the Amtech Imaginera software, the cost is estimated for the flexo post-sheet, litho-lamination and the litho-labeling processes. We did not examine the flexo pre-print process because it has a different market niche than the digital market. Flexo pre-print is only used for a high speed production of a very large print volume. Our research indicates that orders in the range of 200,000 or more prints are required to justify the choice of the flexo pre-print process. As opposed to this, a typical order size for digital printing is under 500 prints. The flexo pre-print process is not competitive in such small order quantities. In other words, the flexo pre-print and digital printing are at two ends of the continuum of the range of order quantities where the process is economically justifiable.

The next section provides cost estimation for the following three processes: flexo post-sheet, litho-lamination, and litho-labeling.

5.1.1 Flexo Post-Sheet

This section shows the cost calculation breakdowns for producing different quantities of a 10” x 10” x 10” 200-B RSC corrugated box for a print job using the flexo post-print process. We estimated the total cost of manufacturing in various batch sizes and the computed price for each unit, which includes a profit of 10% (reduced to 6% for bulk orders). The batch sizes are 1, 10, 50, 100, 500, 1500, 20,000 and 100,000 print orders. Table 4 shows the results with details about all the direct and indirect costs incurred in the production process.

Cost Report for Flexo Post-Sheet - Base Quantity Produced is 1,500 units								
Cost Items	1,500 units	1 unit	10 units	50 units	100 units	500 Units	20,000 Units	100,000 Units
Materials								
Paper Board	440	440	440	440	440	440	5,280	24,933
Ink	100	100	100	100	100	100	1,067	5,333
Plate	800	800	800	800	800	800	800	800
Die	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Direct Cost	2,340	2,340	2,340	2,340	2,340	2,340	8,147	32,067
Production + Labor								
Manufacturing	45	0	0	2	3	15	600	2,700
Set-Up	135	135	135	135	135	135	135	135
Total Production + Labor Cost	180	135	135	137	138	150	735	2,835
Overhead								
Fixed Manufacturing Overhead	435	435	435	435	435	435	435	435
Selling Overhead	160	160	160	160	160	160	160	160
Administrative Overhead	230	230	230	230	230	230	230	230
Total Indirect Cost	1,005	960	960	962	963	975	1,560	3,660
Total Cost	3,345	**3,300**	**3,300**	**3,302**	**3,303**	**3,315**	**9,707**	**35,727**
Profit Margin	335	330	330	330	330	332	582	2,144
Price to Customer	3,680	3,630	**3,630**	**3,632**	**3,633**	3,647	10,289	37,870
Price per unit	2.45	3,630.03	363.03	72.63	36.33	7.29	0.51	0.38

Table 4: Flexo post-sheet cost estimation for different print quantities.

The total cost is calculated as the sum of direct cost and indirect cost. Direct costs include paperboard, ink, printing plates and dies. Paperboard cost includes the cost of corrugation. These costs can be traced to each unit of output. In direct cost, two types of costs are involved, fixed direct cost and variable direct costs and are classified depending upon the print volume. All the paperboard, printing plate, ink and cutting-dies are the fixed direct cost up to a print run of 1500 and they do not change with the print volume up to certain quantity. Whereas, paperboard and ink become variable direct cost as they do change with the number of prints unlike printing plate and cutting-dies for a print run of 1500 or more. For example, a run size of 100,000 units will require 5 times as much paper board and ink as a run size of 20,000 units but same printing plate and cutting-dies can be used for both cases.

Indirect cost includes all the overhead costs, which cannot be traced to each unit but are allocated using the BHR (budgeted hourly rate) as mentioned earlier in Chapter 3. Production and labor costs are indirect costs. They are related to operating the machine as well as the labor incurred during the flexo-folder-gluer operation. The rationale of production and labor cost as an indirect cost is that specialized labor is involved in manufacturing and set-up. These workers are not daily wages or employed on a piece rate system, but are hired on long-term labor contract of 3-5 years on average.

We estimated machine running cost, machine set-up cost and labor cost involved in the production and set-up of machine using the Amtech Software. The cost estimates assume that the machine used for production was a Martin Midline flexo-folder-gluer. A BHR for the machine was already loaded in the software, which includes as a BHR library for different machines used in the industry. Indirect cost also includes all other manufacturing overhead such as machine depreciation and machine maintenance, selling overhead such as sales commissions and sales samples, and administrative overhead costs such as human resource, accounting and governance cost.

Direct and indirect cost constitutes the total cost. Table 5 and figure 8 show the magnitude of direct cost, indirect cost and total cost per unit for different batch sizes for the flexo post-sheet process, in terms of price per unit. For example, table 5 shows that direct cost for 1 unit is $2,340, so the direct cost per unit for 10 unit quantities is $234.

Run Quantity	Direct Cost/Unit (USD)	Indirect Cost/Unit (USD)	Total Cost/Unit (USD)
1	2340.00	960.03	3,630.03
10	234.00	96.03	363.03
50	46.80	19.23	72.63
100	23.40	9.63	36.33
500	4.68	1.95	7.29
1,500	1.56	0.67	2.45
20,000	0.41	0.078	0.51
100,000	0.32	0.037	0.38

Table 5: Price/unit cost for direct, indirect and total cost for different print quantities for flexo post-sheet

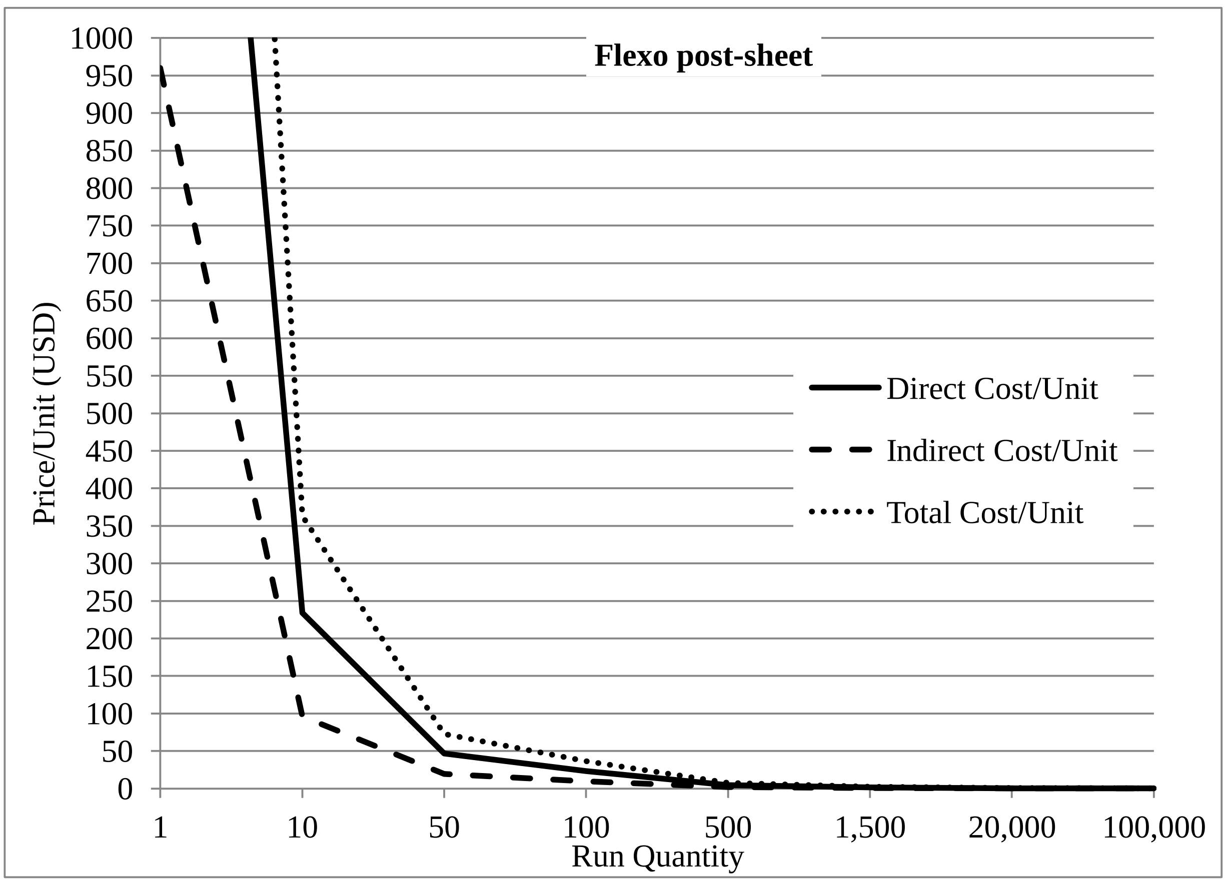

Figure 8: Price/unit cost for direct, indirect and total cost for different print quantities for flexo post-sheet

Figure 8 shows that fixed direct cost is a big part of the total cost for quantities up to 1,500. Due to this reason, it is very difficult for flexo post-print process to manufacture and print small prints runs economically. At 1,500 runs or higher, direct fixed cost is distributed over a large quantity and does not affect the price per unit substantially. At higher print volumes, variable direct cost is a big part of the total cost. It shows that substantial magnitudes of total cost are direct cost. This makes the direct cost highly sensitive to total cost. Figure 9 below shows the zoom in view of 500 units or higher.

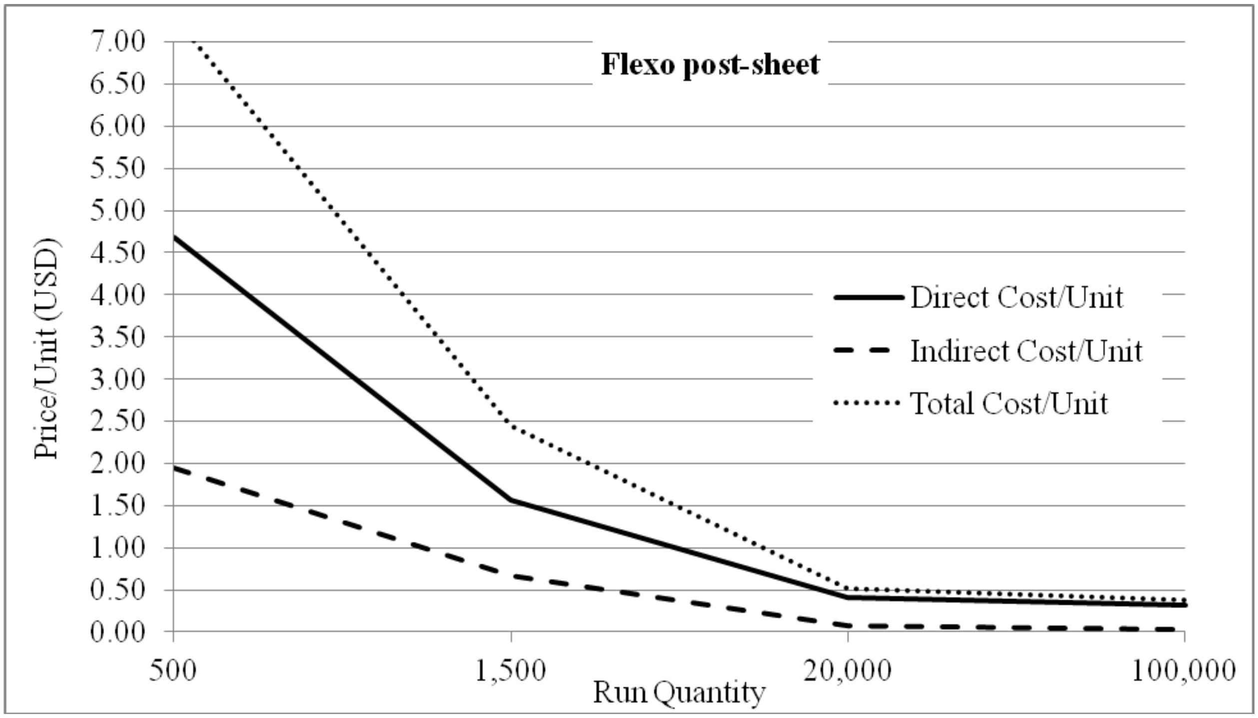

Figure 9: Closer view of the price/unit cost for direct, indirect and total cost for 500 units or higher for flexo post-sheet

The price to the customer per box is the sum of direct cost, indirect cost and profit. A standard 10% profit margin is added to the cost up to 1,500 prints and the profit margin is reduced to 6% for bulk orders. Price per unit is calculated by dividing the total "Price to customer' by the number of units produced.

Assumptions about volume discounts were made in the cost estimation to closely represent industry data. These assumptions were based on interviews with industry professionals. Bulk discounts of 10% and 15% are applied to the paperboard cost for quantities of 20,000 and

100,000 respectively. A 20% ink discount is applied for quantities of 20,000 and 100,000. A 10% labor discount is applied to quantities of 100,000 quantities and higher.

It is clear from the results that as the size of the print order increases, the cost per unit decreases. The reason for the decrease in cost is that as volume increases, several fixed cost and overheads are distributed over a larger number of units, and hence the cost per unit decreases. The result also shows that the flexo-folder-gluer is most cost efficient at 20,000 prints or higher compared to other processes. For example, at 1,500 units, the price per unit is $2.45 which substantially higher than the unit cost of $0.51 for 20,000 units. The overall price is cheaper than litho-lamination; however, flexo post-sheet does not provide the quality of lithography. Results for litho-lamination are discussed next.

5.1.2 Litho-lamination

This section shows cost breakdown for producing a standard-size box for different batch quantities using the litho-lamination process. Similar to flexo post-sheet, costs are indicated as "Price per unit" which includes profit and the cost of manufacturing one box. The cost was calculated for 1, 10, 50, 100, 500, 1500, 20,000 and 100,000 print orders. Table 6 shows the results with all the direct and indirect cost and profit included.

Cost Report for Litho-Lamination - Base Quantity Produced is 1,500 units								
Cost Items	1,500 units	1 unit	10 units	50 units	100 units	500 Units	20,000 Units	100,000 Units
Materials								
Paper Board	305	305	305	305	305	305	3,660	17,283
Printed Linerboard	4,500	1,000	1,000	1,000	1,000	2,000	8,350	27,150
Die	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Direct Cost	5,805	2,305	2,305	2,305	2,305	3,305	13,010	45,433
Production + Labor								
Manufacturing	240	0	2	8	16	80	3,200	14,400
Set-Up	125	125	125	125	125	125	125	250
Total Production + Labor Cost	365	125	127	133	141	205	3,325	14,650
Overhead								
Fixed Manufacturing Overhead	170	170	170	170	170	170	170	340
Selling Overhead	80	80	80	80	80	80	80	160
Administrative Overhead	110	110	110	110	110	110	110	220
Total Indirect Cost	725	485	487	493	501	565	3,685	15,370
Total Cost	6,530	2,790	2,792	2,798	2,806	3,870	16,695	60,803
Profit Margin	653	279	279	280	281	387	1,002	3,648
Price to Customer	7,183	3,069	3,071	3,078	3,087	4,257	17,697	64,452
Price per unit	4.79	3,069.18	307.08	61.56	30.87	8.51	0.88	0.64

Table 6: Litho-lamination cost estimation for different print quantities

The cost estimation format is quite similar to the flexo post-sheet cost estimation. Total cost is the sum of direct cost and indirect cost. In the direct cost, instead of ink and printing plates, printed linerboard is included. Litho-lamination uses a lithographically printed linerboard pasted to a single face corrugated blank. Therefore the linerboard cost estimate includes cost of the lithographically printed linerboard. It is assumed that the linerboard is printed independent of the facility that combines the corrugated board. It is added as a separate cost in the software. Likewise the “paper board” is the estimated cost of single-face corrugated sheet.

Production and labor costs are almost similar to flexo post-sheet as calculated by the Amtech software. The difference is that set-up cost doubles at higher runs of 100,000 for litho-lamination. The reason for doubling the set-up cost includes operator shift change and/or machine cleaning. The machines assumed for production were an Automatan laminating machine, a one-cut auto-platen die-cutting machine, and a unitized banding machine. The costs of these machines were already loaded in the software library. Overhead costs are lower than the flexo post-sheet as printing is done independent of the lamination facility. Similar to set-up cost, overhead costs are assumed to double at 100,000 prints. With a big print order, more overhead is associated. Table 7 and figure 10 below show the magnitude of direct, indirect and total cost per unit for different batch sizes for the litho-lamination process.

Run Quantity	**Direct Cost/Unit (USD)**	**Indirect Cost/Unit (USD)**	**Total Cost/Unit (USD)**
1	2305	485.16	3,069.18
10	230.5	48.66	307.08
50	46.1	9.86	61.56
100	23.05	5.01	30.87
500	6.61	1.13	8.51
1,500	3.87	0.48	4.79
20,000	0.65	0.18	0.88
100,000	0.45	0.15	0.64

Table 7: Price/unit cost for direct, indirect and total cost for different print quantities for flexo post-sheet

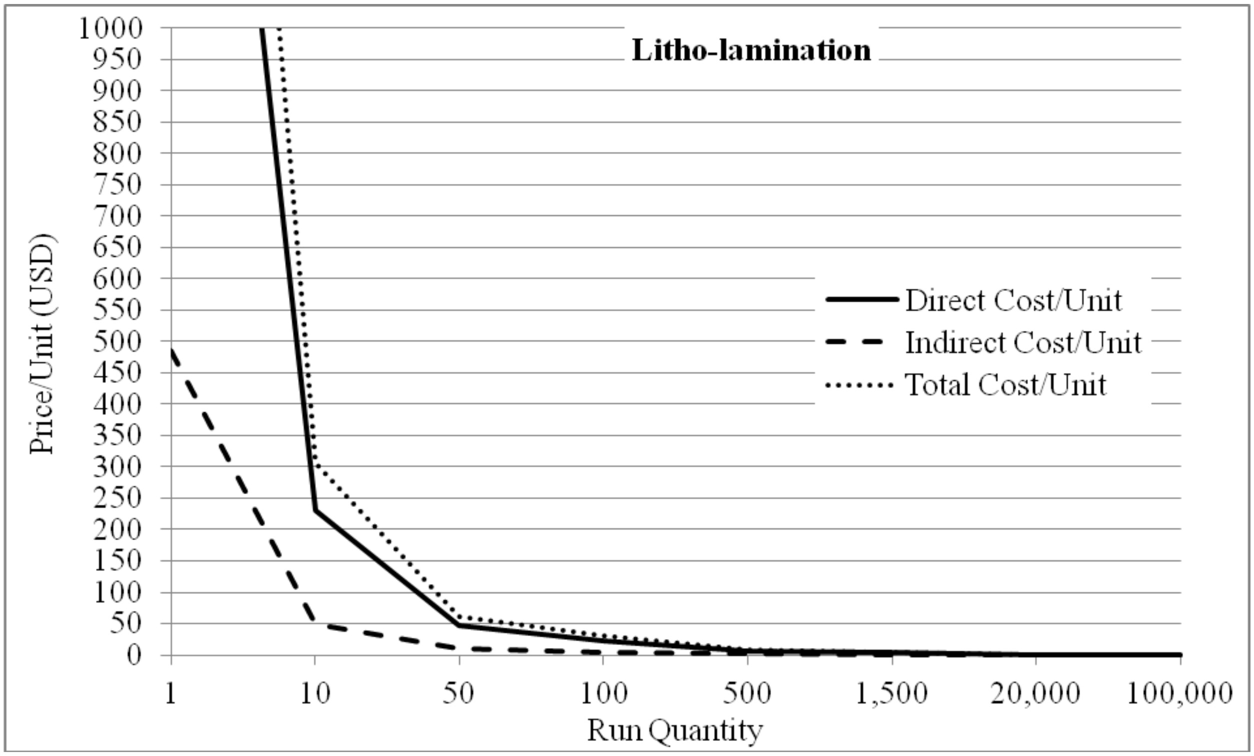

Figure 10: Price/unit cost for direct, indirect and total cost for different print quantities for litho-lamination process

Like flexo post-print, the direct cost is a big part of total cost. Fixed direct costs are prominent up to 500-1,500 units, and for higher quantities variable direct cost becomes more prominent. Direct cost is a big part of total cost and independent corrugated companies have no control over the prices of direct costs for example paperboard. Independent corrugated companies only control indirect costs. Hence, independent corrugators strive to run manufacturing plants very effectively and efficiently to reduce total indirect cost and offer low prices to the customer.

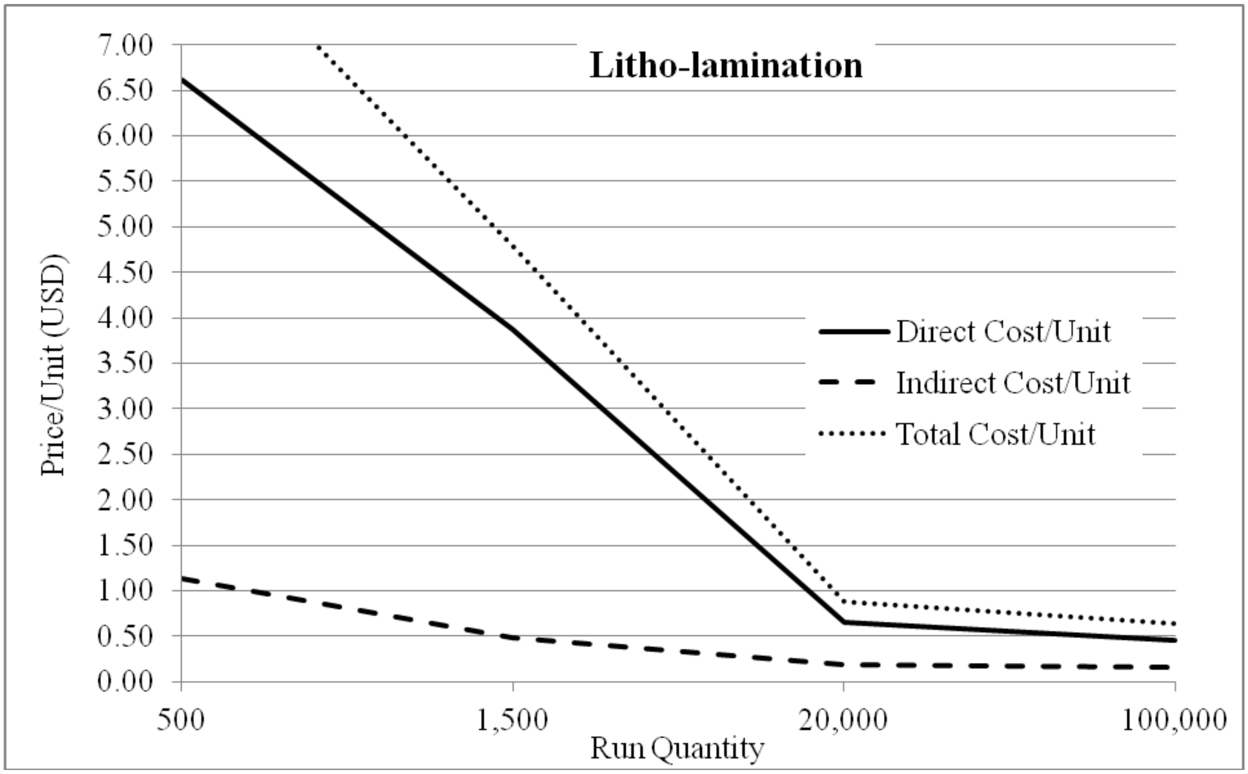

Figure 11: Closer view of the price/unit cost for direct, indirect and total cost for 500 units or higher for litho-lamination

The price to a customer was calculated the same way as flexo post-sheet. Figure 11 shows a closer view of the costs. A standard 10% profit margin is added to the cost up to 1500 prints, and the profit margin is reduced to 6% for bulk orders of 20,000 or higher. Price per unit is calculated by dividing the "Price to customer' by number of units produced.

The unprinted paperboard price assumptions were same as flexo post-sheet and were 10% and 15% for bulk orders of 20,000 and 100,000 quantities respectively. A 10% labor discount is applied and as mentioned earlier, the set-up and overhead cost is assumed to double for 100,000 quantity increments.

The cost per unit decreases with the increase in the number of print orders. The cost of printed linerboard remains constant up to 250-300 sheets because small run jobs are not prevalent in the lithographic printing industry. At 1,500 units, the estimated cost per unit is $4.79 compared to flexo post-sheet where the estimated cost per unit was $2.45. Although the price is higher, litho-lamination offers great printing quality. The results also show that litho-lamination is most cost efficient at print quantities of 20,000 prints or higher. However, results indicate that flexo post-print is a substantially less expensive option for the same volume if quality is not a concern. Another process that offers a high print quality is litho-labeling, which is discussed in the next section.

5.1.3 Litho-labeling

This section shows the cost estimation results for litho-labeling. Table 8 shows the cost estimation of different quantities of a standard 200-B RSC10x10x10in box produced using the litho-labeling process. In litho-labeling, a label is pasted on to double face (single wall) corrugated board.

Cost Report for Litho-Labeling - Base Quantity Produced is 1,500 units								
Cost Items	1,500 units	1 unit	10 units	50 units	100 units	500 Units	20,000 Units	100,000 Units
Materials								
Paper Board	440	440	440	440	440	440	5,280	24,933
Printed Labels	3,375	750	750	750	750	1,500	6,263	20,363
Die	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Direct Cost	4,815	2,190	2,190	2,190	2,190	2,940	12,543	46,296
Production + Labor								
Manufacturing	230	0	2	8	15	77	3,067	13,800
Set-Up	125	125	125	125	125	125	125	250
Total Production + Labor Cost	355	125	127	133	140	202	3,192	14,050
Overhead								
Fixed Manufacturing	170	170	170	170	170	170	170	340
Selling Overhead	80	80	80	80	80	80	80	160
Administrative	110	110	110	110	110	110	110	220
Total Indirect Cost	715	485	487	493	500	562	3,552	14,770
Total Cost	5,530	2,675	2,677	2,683	2,690	3,502	16,094	61,066
Profit Margin	553	268	268	268	269	350	966	3,664
Price to Customer	6,083	2,943	2,944	2,951	2,959	3,852	17,060	64,730
Price per unit	4.06	2,942.67	294.42	59.02	29.59	7.70	0.85	0.65

Table 8: Litho-labeling cost estimation for different print quantities

The cost estimation method is similar to the litho-lamination process. However, the direct cost of litho-labeling is different than the litho-lamination. The paper cost is higher in litho-labeling as four plies of paperboard are used, as compared to litho-lamination where three plies are used. Therefore, there is an increase in direct material cost. But cost of the printed labels is only 75% of the estimated cost for litho-lamination. In litho-lamination, the size of printed sheet needs to be equal to the size of the corrugated blank however in litho-labeling, size of label is always smaller than the size of the corrugated blank.

The estimated die cost is same in all three processes because the same size cutting-die was used. In flexo post-sheet, the die is mounted to the flexo folder-gluer machine followed by strapping. However in litho processes, a one-cut auto-platen die-cutting machine is used. Hence, the litho process employs two machines; one for laminating or labeling and one for die-cutting which also performs strapping.

Overhead and set-up cost are assumed to double for quantities over 100,000. A 10% labor discount is also applied print volumes of 100,000 or higher. The same profit margins are applied as the other processes, i.e., 10% for less than 20,000 prints and 6% for 20,000 or higher. A 10% and 15% quantity discount is also applied for quantities of 20,000 and 100,000 respectively.

Run Quantity	Direct Cost/Unit (USD)	Indirect Cost/Unit (USD)	Total Cost/Unit (USD)
1	2190.00	485.15	2,942.67
10	219.00	48.65	294.42
50	43.80	9.85	59.02
100	21.90	5.00	29.59
500	5.88	1.12	7.70
1,500	3.21	0.48	4.06
20,000	0.63	0.18	0.85
100,000	0.46	0.15	0.65

Table 9: Price/unit cost for direct, indirect and total cost for different print quantities for flexo post-sheet

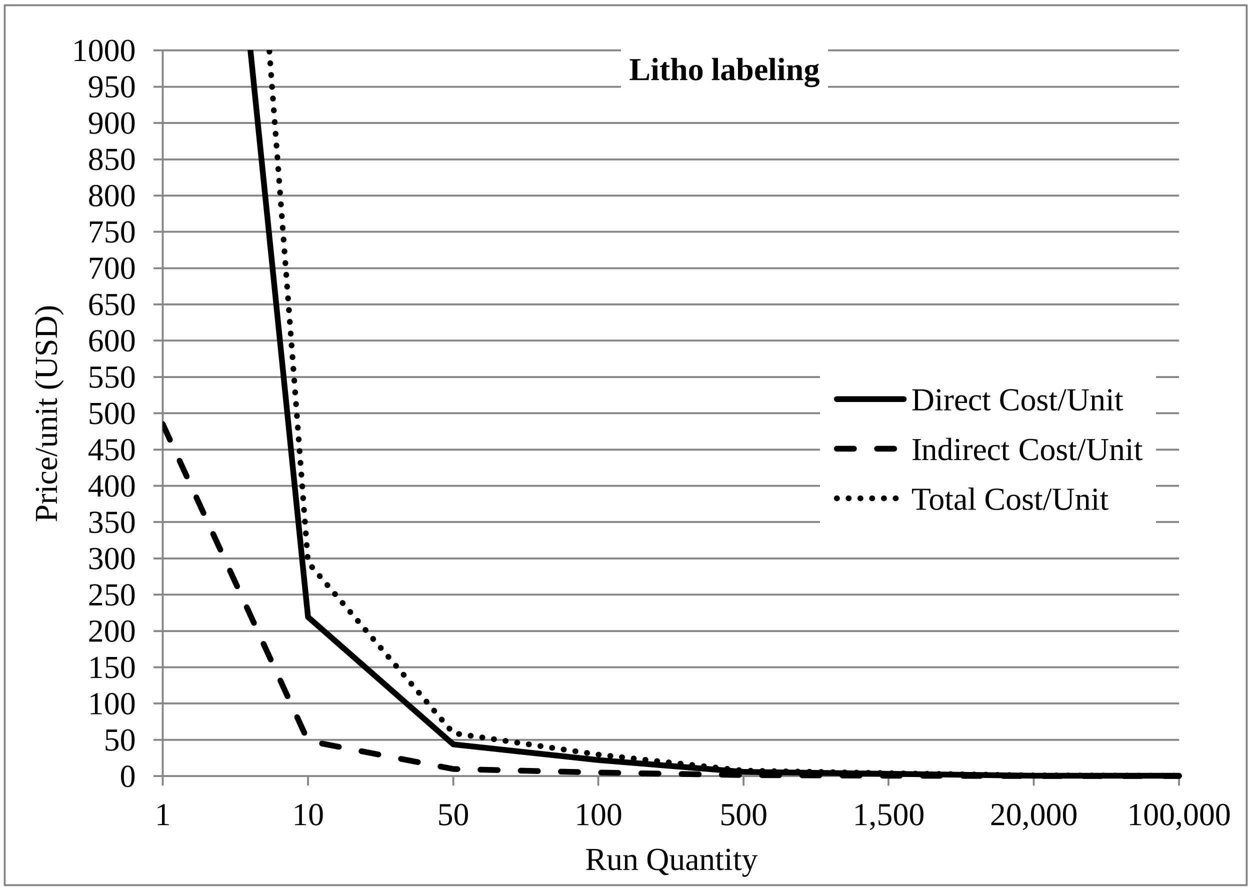

Figure 12: Price/unit cost for direct, indirect and total cost for different print quantities for litho-labeling process

Table 9, figure 12 and figure 13 show the direct, indirect and total cost for different print quantities for litho-labeling process. Again, very similar to litho-lamination, direct cost is the biggest part in the total cost followed by indirect cost. The fixed direct cost such as printing plates is the big part, which makes all these processes uneconomical for small runs. Digital printing process has lower fixed direct cost as it does not use printing plates and hence economical for short run orders.

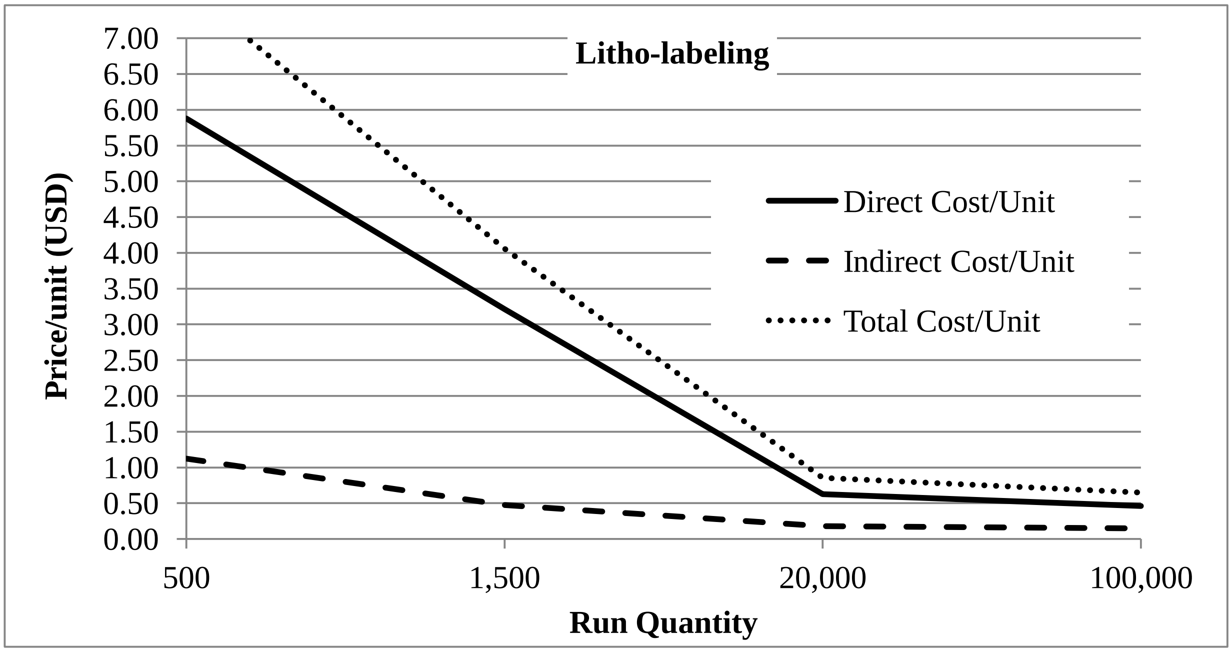

Figure 13: Closer view of the price/unit cost for direct, indirect and total cost for 500 units or higher for litho-labeling

5.2 Comparison

A summary of the results for all three processes is shown in Table 10 below.

No. of boxes	Flexo Post-sheet (USD)	Litho-Lamination (USD)	Litho-Labeling (USD)
1	3630.03	3069.18	2942.67
10	363.03	307.08	294.42
50	72.63	61.56	59.02
100	36.33	30.87	29.59
500	7.29	8.51	7.70
1500	2.45	4.79	4.06
20000	0.51	0.88	0.85
100000	0.38	0.64	0.65

Table 10: Summary of cost comparison for different printing techniques

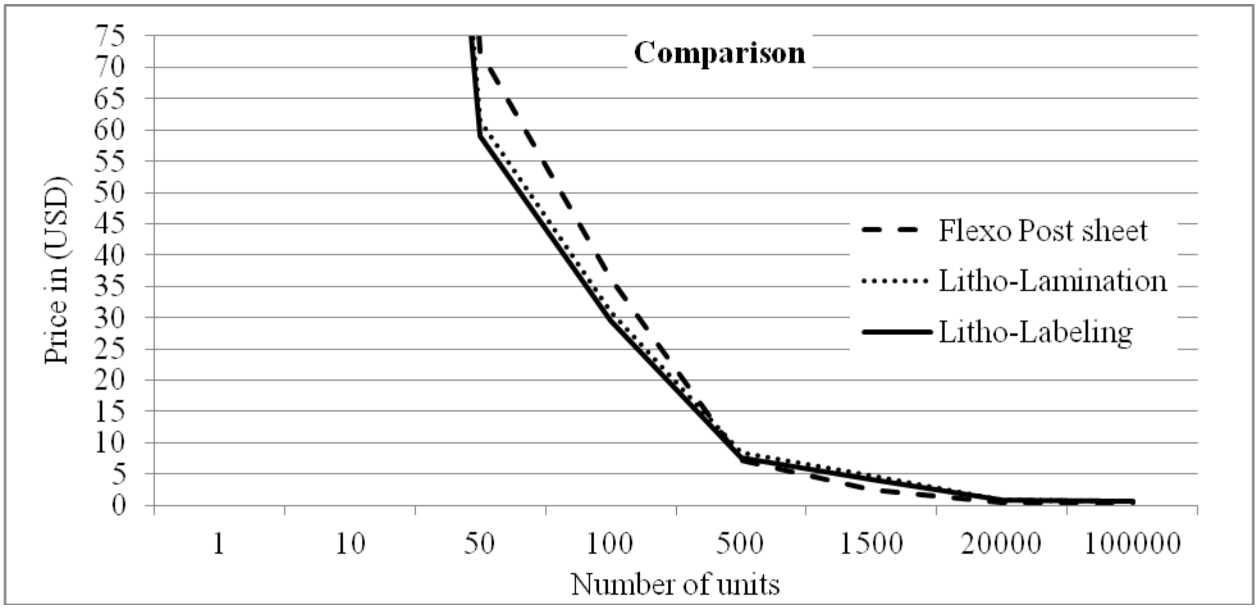

Figure 14: Price/unit cost comparison for direct, indirect and total cost for different print quantities

Figure 14 shows that none of the processes are cost efficient in small quantities of up to 100 units. As the number of units increases, the costs per unit start declining steeply. At a batch size of 100,000 units, the flexo post-sheet is the most economical of the three processes. The estimates price to manufacture, print and die-cut a box using the flexo post-sheet is 38 cents compared to 64 cents for litho-lamination, and 65 cents for litho-labeling. Price drops sharply with an increase in print quantities, which signifies that these processes are basically designed for long runs or higher batch sizes. However, currently, litho-labeling is the preferred process in the industry for short runs of up to 1,500 to 2,000 print runs. Everyday 20 to 50 low volume job orders are processed through litho-labeling process (Barnes 2011). The flexo pre-print process is only cost effective at large order sizes of 100,000 or above. Similarly, litho-lamination is cost effective for a print order of 20,000 to 100,000. Litho-labeling is cost effective for low volumes from 500 to 20,000.

The machines used in the cost estimation process are the standard machines used in the industry including Martin Midline flexo-folder-gluer, Automatan laminating and labeling machine and one-cut Autoplaten flat-bed machine for die-cutting.

It is likely that there are other factors, which can affect the final price of the box. These factors include size and speed of the machine, skills of the operator, number of jobs printed in one pass, the company's supply chain management, etc. However, these factors are unlikely to make a substantial difference to the relative costs of the three processes.

5.3 Process Drivers: Volume, Quality and Speed

This research finds that the main cost driver is the print quantity or volume of order. It is apparent from the results that all these processes are cost-efficient for high order volumes. However, quality is another critical factor that influences the adoption of a process for printed corrugated box production. Digital printing is predicted to be most cost efficient around 500 print quantities.

Quality of print is second most critical cost driver. As mentioned in the literature review, lithography produces the highest quality print because it can process high screen resolutions. Field discussions with a key industry specialist results in the following ranking of quality in the following from best to worst (Barnes 2011):

Rank 1 – Litho-Lamination

Rank 2 – Litho-Labeling

Rank 3 – Digital Printing

Rank 4 – Flexo pre-print

Rank 5 – Flexo post-sheet.

Litho-lamination produces the highest print quality whereas flexo post-sheet offers the lowest quality. For a customer, a primary driver of choice of a printing process is the quality of final output. If a customer wants a very high print quality, the litho-lamination process is the most appropriate choice. If quality is not a concern for a customer or if the box is a single color job, flexo processes is the most cost effective option. Digital printing offers medium quality, better than flexo, but comparable to litho process.

The third main driver, especially in relation to digital printing, is the speed of the process. Digital printing is a slow process in comparison to other process. Among all the processes, flexo post-sheet has the highest speed followed by litho-lamination, litho-labeling and digital printing (Barnes 2011).

Digital printing produces a significantly fewer prints per hour. For example, a digital press typically produces 100 to 200 boxes per hour where as other processes produce thousands of boxes per hour. Litho-lamination and labeling can produce more than 5,000 boxes per hour, and flexo post-sheet from 13,000 to 25,000 boxes per hour. Speed is an important factor because if a customer wants to print 10,000 boxes, a significant time lag is required if digital printing is used whereas other processes can complete the job in less than a day.

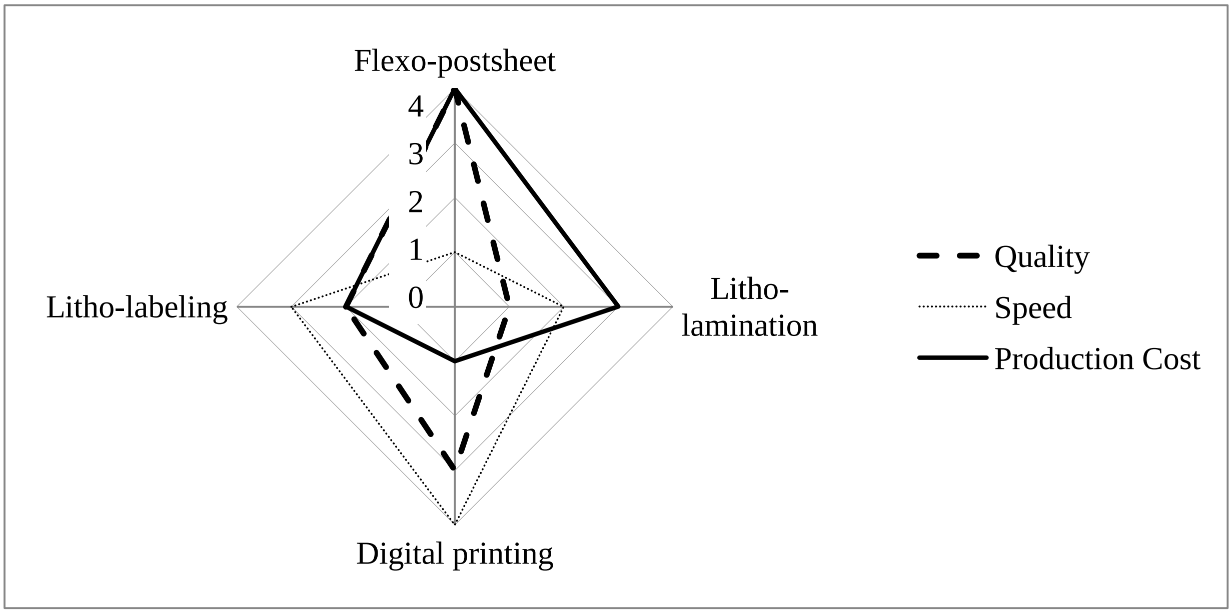

Figure 15: Radar Chart showing the combined cost drivers

To represent the combined effect of all the cost drivers of a printing process, Figure 15 shows a radar chart displaying the ranking of three main drivers associated with a particular printing process. In the chart, as the numbers increase from 1 to 4, ranking of quality decreases, speed of process decreases, and production cost increases. The production cost considered only for small print orders. A long-print order is not included in the analysis because the primary objective of the research is to compare alternative printing process to digital printing. Figure 12 shows that if a customer chooses flexo post-print process for lower print volume, it would be uncompetitive for cost efficiency and quality. Similarly, for the litho-labeling process, the print quality will be superior and the cost will be lower than the flexo process, but production speeds would be lower.

The closest competitor to digital printing for each major dimension of performance, i.e., quality, cost, and speed, can be seen from the Figure 16 below.

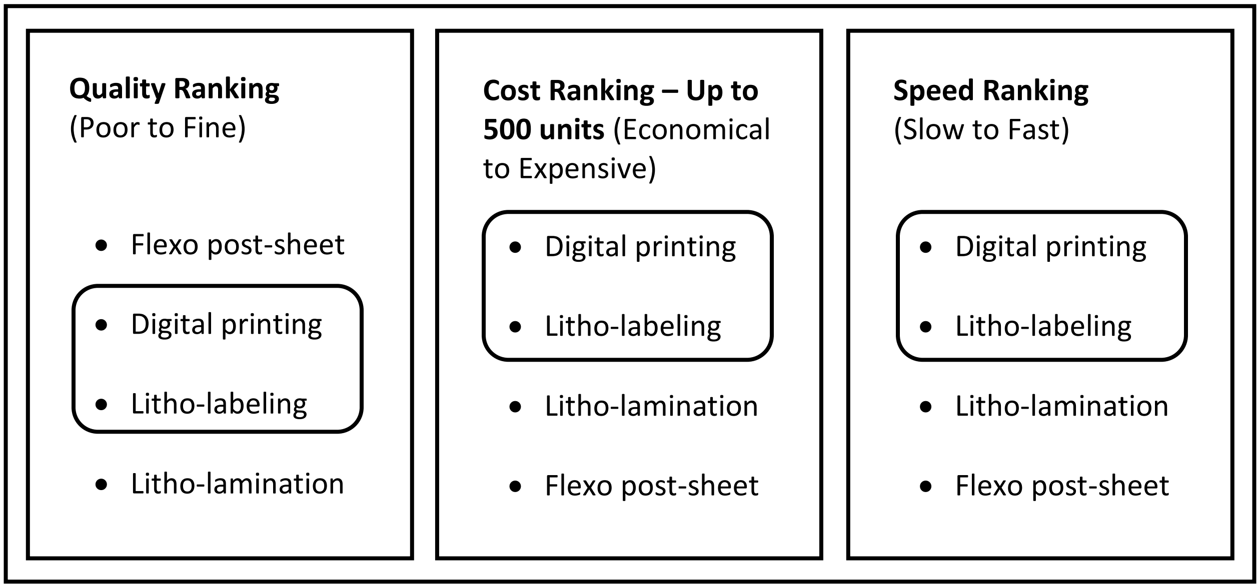

Figure 16: Closest competitor to digital printing for small volume

Figure 16 shows that litho-labeling is the closest competitor to the digital printing based on quality, cost and speed of the process. Litho-labeling ranks second and digital ranks third in quality. Cost estimation results show that litho-labeling is the cheapest process for low volumes among all three considered. No data for digital printing cost estimation were available. Based on field interviews with digital printing machine manufacturers and industry professionals, digital printing technology is designed for short runs and produces superior quality relative to flexo post-print and comparable quality to lithography. Hence, the cost of digital printing cost should be lower than the cost of litho-labeling for short runs. In terms of speed of production, litho-labeling has a higher speed than digital printing but it ranks closest to the digital printing.

Digital printing offers attractive features for short run printing. Because no printing plates are required, the fixed direct cost to the customers can be reduced. However, paperboard cost and cost of the cutting-die will be a big part of the fixed direct cost. The options for paperboard cost are to keep an inventory of standard sizes corrugated blanks and print and die-cut it for the customer requirements. The additional cost with this is the die and a greater waste of corrugated board. A two-up job could reduce the wastage if production planning is done correctly. And for die-cutting, currently two options are available:

a) Using the same die-cutting method as other technologies. This includes a die and a fixed direct cost to the customer.

b) Use a CNC cutting table such as Kongsberg cutting table. This option does not include a die however the process is slower than die-cutting.

The latter option appears to be better because the main purpose for digital printing is to provide a cost efficient way of producing high end colorful corrugated boxes in small order quantities. With no fixed direct cost to the customer, the total cost for producing small volume corrugated boxes will be useful to the fast moving, low inventory retail market. Additionally, digital printing can offer other advantages such as variable data printing and print on-demand.

Research used a 10” x 10” x 10” RSC box for cost estimation purposes. If the box of different size was used, the direct costs would vary accordingly. For example, if a RSC box of size 20” x 20” x 20” was used, the corrugated blank size would be 40” x 82”. The board MSF is four times the 10” x 10” x 10” RSC box. Also, a four time bigger cutting-die would be required as well along with more ink and bigger printing plates. It clearly shows that the material cost will increase by four times. Similarly, if the size of the box decreases, all fixed direct changes accordingly such as cutting-dies, printing plate, buyouts and inks. Indirect cost/unit will also change as output of machine will increase or decrease depending upon the size of the box. The magnitude of direct cost and indirect cost depends upon the size of the box.

Chapter 6

Conclusions

The purpose of this research was to report the primary cost drivers in selection of a particular process to print corrugated boxes. This research explored the estimated cost of producing a printed corrugated box using the traditional processes, with special emphasis on low volume. Cost estimation results were compared to find the most competitive process to digital printing process. In order to understand the economics of corrugated box manufacturers, field visits to corrugated manufacturing plants was done, personal interviews were conducted with the industry and academic professionals. Data was generated using market prices and Amtech Imaginer software. Data reveled that volume of print is one of the key driver in selection of a corrugated box manufacturing and printing process. Quality and speed are the other main drivers. The most competitive process to digital printing process is litho-labeling.

In conclusion, it is likely to be difficult for digital printing to compete with other processes available in the market due to its slow speed, medium quality and inability to produce large volumes. It would likely not be able to compete with flexo preprint at all due to very high volume requirement of the process which contradicts with digital printing economics. The closest competitor to digital printing is litho-labeling in terms of quality and volume.

The research is important for corrugated box industry. Currently, few short volume orders are processed due to the high fixed direct cost involved in the manufacturing and printing. Digital printing has the unique economic of manufacturing and printing short volume in a cost efficient manner. By understanding the importance of digital printing process, corrugated box industry can serve the short volume, variable data printing and colorful graphic needs of the fast moving retail sector in a better way. During the course of the research, one of the information sources in the research, installed a corrugated digital printing machine and digital CNC machine to print short volume POP displays.

Digital printing has the capability to serve a different market segment where variable data printing and short print run is required. The fixed direct cost is not incurred in digital printing. Currently digital printing is economically sustainable up to a print run of 500 units (Arzoumanian M 2011). If speed of the digital process can be increased, there is a potential market. One key informant summed it up: “There is a potential market for digital printing if the speed can be increased” (Barnes 2011).

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