An Improved Automated Workflow for Digital Photo Print Production

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Abstract

Changes in the photo industry have moved printing demand to more complex order compositions, consisting of multiple sizes of final prints. Customers are requiring the variety of multiple "standard" and non-standard sizes within a single order. Current photo printing & processing equipment designs were developed based on a standardization of product (e.g. print sizes) and on the principles of "batch processing", with multiple production steps. Existing printing equipment does not have the flexibility to intermix a variety of sizes, nor to easily print "non-standard" sizes. "Mixed size" orders require multiple print batch runs, sometimes on different printers. Handling "mixed size" orders is consequently labor intensive, requiring multiple machines, manual sorting, manual collating and sometimes manual cutting.

Current workflows and systems evolved from the principles and practices of batch manufacturing, which has been the main stay of manufacturing for the last century. Opportunity exists for to convert the photo printing process from a batch process to a flow process utilizing the principles of "Lean Manufacturing". The development of a new printer system and workflow is described.

The Chromira Pro Lab system was designed to bring Lean Manufacturing processes and principles to professional photo printing. Mixed size order printing is converted from a "batch" process to a "flow" process. Multiple and mixed sized orders are printed and processed concurrently, and in a continuous flow. Previously manual operations required for handling multiple sizes are automated or removed. Reliance on "standard" sizes is completely eliminated. The process is re-designed from the "ground up", replacing multiple pieces of equipment with one. The result is a system that delivers complete orders consisting of multiple sizes, ready to ship, without manual handling. Complete and automated integration into existing software image workflow systems is achieved without compromising any new workflow efficiency gains. Integration of Lean Manufacturing principles throughout the photo production process generates additional, consequential, related efficiencies.

Introduction and Background

Traditional photo finishing workflows, both professional and consumer, evolved to handle efficient production of high volumes of standardized prints. In this context, "standardized" meant a small selection of common sizes, with little or no ability to customize the final result in size, content, color, or composition. In time, consumer photo finishing workflows evolved from large batch processing (e.g. printing in long rolls) in central plants, to distributed processing in smaller batches (e.g. mini-labs). Smaller batch workflows based on "mini-labs" offer an improvement over large batch processing, but generally have the same limitations to sizes and customization. (Most "mini-lab" workflows offer automatic printing for two standard sizes, but without automatic collating. Printing other than the two standard sizes requires a manual paper change.) In the world of consumer printing, the vast majority of prints were produced because that was the only way to actually *see* the captured image. The majority of those prints were not worth keeping anyway, never mind customizing, reprinting or enlarging. Consequently, the restriction on the number of print sizes available posed little problem. Professional "proof" printing was no different than consumer printing, except for the care taken and printing quality provided. Customization existed only for "re-prints", and primarily only for professional work. The customization that did occur, was minimal: labor intensive (e.g. expensive) cropping, and color correction.

The conversion to digital cameras, with the ability to preview and delete images, removed the primary purpose of consumer photofinishing and quickly destroyed that business. While the quantity of captured images grew, the number of images printed decreased. The only images printed, are images that the consumer actually wants. In the professional context, the printing of "proof" images transitioned for the most part to soft viewing methods. In both the professional and consumer contexts the remaining printing primarily provides images that the end user wants to keep. The increased importance of the final result to the consumer generates more care and consideration in the selection of the final prints, which in turn generates more variation in print sizes within orders. Printing workflows, however, have never evolved beyond producing standard sizes of prints, in batches, sorted by print size.

In the professional world, the transition from optical to digital printing, drove some producers to transition from a batch process (e.g. roll to roll printing) to partial flow process (e.g. using digital mini-labs). The transition to a flow process, however, is incomplete because production must still be handled in print size denominated batches. Multiple sizes of prints within a single order must still be manually located and collated. A system for concurrently printing and collating mixed size orders, is required to complete the conversion to a flow system.

Goals for New System

The goals for the new system are to improve photo production operations by changing batch processing workflows to a fully integrated Lean Manufacturing workflow. As applied to photo print production, the principles of Lean Manufacturing are:

Simplify

1. Remove steps in production process. Combine multiple production steps into a single machine.
2. Decrease equipment. Simplify the production environment by decreasing the variety of machines.

3. Fewer types of inventory. Eliminate the need for carrying and managing multiple sizes of material in inventory.
4. Decrease training requirements. Decreasing the variety of machines eliminates training for all the removed equipment.
5. Less Maintenance. Decreasing the variety of machines eliminates maintenance for all the removed equipment
6. Simplify data flow: eliminate assignment of images to respective printers, decrease tracking through production process.

Reduce labor via automation and improved work flow.

Automating the handling of mixed sizes of orders removes labor in: loading and maintain multiple paper cassettes, change paper sizes during printing, locating, sorting and collating mixed sizes of prints within an order. For producers using roll to roll printers batch sizes are extremely large adding additional labor "between machines" of: unloading exposed paper and transporting it to the processor, transporting exposed paper to cutters, setup and cutting, and finally collating.

Shorten overall production cycle / Faster turn-arounds (JIT)

Smooth, one-step, production flow vs. Batch

Eliminate cycle of: "Print, process, (sometimes) cut, collate and sort". Eliminate or decrease the bottlenecks at each process. Bottleneck examples include: long rolls running through a processor or cutter, large piles of prints waiting for collating, QC or bagging,

Increase flexibility of manufacturing process

No special setups should be required regardless of print sizes, mix of sizes, or "non-standard" sizes.

Decrease waste

1. Combine orders during printing for maximum material yields
2. Eliminate remakes for color mismatches

Reduction of wasted effort (labor)

1. Reduce of material handling from step to step
2. Reduce of setup times of multiple machines
3. Eliminate color matching between sizes of materials
4. Eliminate color matching between multiple machines
5. Reduction of maintenance of multiple machines

Minimize inventory carrying

With fewer inventory line items to stock, the total value of inventory being carried can be decreased

Decrease space requirements

1. Fewer machines
2. Minimize floor space requirements for the 1 remaining machine
3. Eliminate dark rooms required for 1) Processors, and 2) Paper loading
4. Decrease packaging and handling space required.
5. Decrease space required for storing inventory.

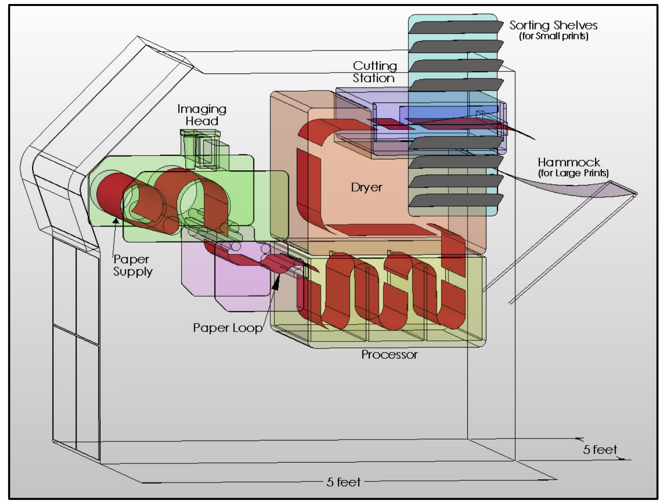

Figure 1

Design of the New System

The new system was to be designed to replace both large batch (e.g. roll to roll printing), and the smaller batch workflows. Designing for a full *flow* type workflow began with a review of all the functions in the photo manufacturing process. Following the "flow" of the process from start to end, the required system functions are: paper supply handling (e.g. paper cassette), paper cutting, printing (e.g. print engine, back printing, pre-processing material buffer, processing, drying, cutting, sorting, collating, QC, and finally bagging.

We started with the concept that we would produce all sizes of prints from a single 30" wide web of material. Eliminating all but one size of material generates three immediate benefits: 1) Any print size can be produced as easily as any other, 2) All sizes of prints are perfectly color matched. Color match is "free" and automatic because all prints come from the same web of material and 3) Inventory management is reduced to a single size of material.

Removing the need to frequently change paper sizes immediately calls into question the value of "quick change" paper cassettes. We settled on the concept of eliminating the paper cassettes. In addition to the obvious value of removing components, discarding the cassettes also eliminated the need for a darkroom in which to load them. Of course loading photographic material still requires complete darkness, so for this we resurrected an old "tried and true" and "low tech" system of light trapping. The operator reaches into the printer through opaque cloth sleeves. With the paper mounting at a comfortable height loading through the sleeves is easy and acceptably fast.

For printing we used our standard Chromira 5X print engine. Unlike most mini-labs, Chromira print engines print continuously from a roll, with no print length limitations. Consequently, cutting the web occurs after printing. After cutting, normal practice is to "buffer" exposed material prior to processing. Buffering the material serves to provide a waiting period after exposing and before processing for the latent image decay characteristics of the material to stabilize the image. Holding the material long enough between exposure and processing makes it relatively insensitive to time inconsistencies at this stage of the process. Buffering also serves the important function of allowing a comparatively slow printer to feed prints to a normally faster processor. Buffers, however, take up space. Buffering also slows the process, by the amount of the waiting period. To avoid both of these disadvantages, we took a different approach and eliminated the traditional buffer. We synchronized the speed of the printer with processor. In place of the buffer, we added a simple direct roller transport to move the paper from the printer to the processor. With the printer and processor running at exactly the same speed, we needed only to figure out how to couple the intermittent, line by line, advance of the printer, with the continuous flow of the processor. This was resolved with a simple and very small loop, located at the entrance to the processor. With this system, the time from exposure to processing is always consistent, and prints of any length can be printed continuously without having to “buffer” a long print.

While our goal includes eliminating multiple pieces of machinery and consolidating the functions into one, it also includes reducing the space requirements. Ending up with one machine, that is as large as the sum of the equipment replaced, is not the result we are looking for. Removing the buffer section provided a good first step. However, when analyzing all of the necessary components (listed above), the manufacturing process might easily stretch out horizontally, ending up with no significant space savings. To minimize the amount of floor space required, we took the approach of “stacking” the components. Referring to fig.1, the print engine was stacked above the cutter and the transport system (which replaced the buffer). The required floor space for the wet section of the processor was relatively prescribed. To shorten the overall package, the functions of drying and cutting were stacked on top of the processor. This architecture reduced the overall footprint by approximately 30%.

Referring again to fig. 1, the stacking of the components resulted in a longer than usual paper path in the drying section. This resulted in the first of several unanticipated benefits. The longer paper path provides more time for drying, enabling lower drier temperatures and lower energy consumption. Typical dryer power consumption is around 600 watts, compared with 2,400 – 4,800 watts found in common roller transport processors.

After drying, the paper enters the cutting and back printing station. Prints that are smaller than 12” (on the short side) are cut and ejected onto the sorter shelves. Prints that are larger than 12” exit the rear of the machine onto a collection “hammock”. The sorting shelves work in coordination with the cutting to collect prints into the appropriate shelf for collating with the rest of their respective order.

Internal Workflow Description

Cutting all prints from one wide 30” removes the need for all print size denominated batch processing. Prints can be imaged and cut in any order without regard to print size. Print sizes can be intermixed without restriction. Printing images that don’t fill the entire width of the web, however, can generate a significant amount of un-imaged scrap material. Very small orders, if printed individually, can reduce material yields to unacceptable lows. Printing higher quantities of images however provide the opportunity to “nest” multiple images across the width of the paper web, filling in most, and frequently all, of the area available. Combining multiple orders provides a sufficient quantity of images to achieve high material yields, even if the individual orders themselves are very small. The Chromira Pro Lab automatically intermixes the prints from all queued orders, then nests them together for maximum paper utilization. At the end of the process, the cutting station, in conjunction with the sorter shelves, “de-nest” (e.g. separate) the individual prints and collate them into separate shelves. All prints for an individual order are not necessarily delivered sequentially. The printing order is calculated (and the images nested) to maximize the material yield. Once all images for a particular order have been delivered to that order’s assigned sorter shelf, the operator is notified and the completed order can be removed from the shelf. The order is ready for QC, or bagging.

Unanticipated Surprises

Throughout the course of development of this project, several un-anticipated surprises turned up. Some were positive, some undesirable.

Positive Surprises

The first positive surprise was in the area of power consumption. The comparatively long paper path through the dryer provided approximately one additional minute of drying time. This significantly decreased the amount of power needed to dry the paper. Typically, 30” processors utilize between 2,400 and 4,800 watts in their dryer sections. The longer paper path enables complete drying of the material at a nominal power consumption of 500 watts. (Power rates vary. One customer reports cost savings of $300/month.)

After field trials began, we received reports of unexpectedly high consistency in B/W printing on color RA4 materials. When printing B/W images on color RA4 materials, it is normally difficult to eliminate all color from the image (e.g. to maintain a perfectly neutral balance). Perfect calibration of the printing system and processor are required. Even with the most careful of calibration, a subtle magenta cast across the image is a common occurrence. Upon analysis we have surmised that the usually inconsistencies stem for latent image instability and are the result of inconsistent delay times between printing to processing. We credit the removal of the buffer from the system, and the extremely consistent time interval from printing to processing, with this benefit.

The conversion from batch to flow production surprised our customers in the effects it has had on some *non-printing* related aspects of their production flow. Flattening of the labor peaks and valleys generated by the previous batch workflow have caused a decrease in “overtime”, and an overall increase in production capacity due more efficient utilization of the labor. The “rush-wait-rush-wait” work pattern is completely eliminated. Labor that was previously required to service the peaks is reassigned to other duties. Rush or panic orders can now easily slip into the front of the production flow queue. A completed rush order can be printed in 10-15 minutes, with zero disruption to the normal production flow.

The back-printing module is located in the cutting station. It is positioned such that all prints pass over the back-printer as they exit to the sorter trays. When customers requested a third line of back-print information, it was a fairly easily provided with a software change.

Undesirable surprises

Matching the workflow through the printer, to both the external image processing workflow, and to the incoming data flow turned out to be necessary. Maximum print nesting yields are obtained from a continuous flow of images to be printed, and with a reasonable queue of images available to "nest" across the 30" wide web. When the first file arrived in the printer's queue, with no other images available to use for nesting, it was immediately rendered and printed alone on the web. This was solved relatively simply by setting thresholds. Images stayed in the queue, and were not printed, until there were sufficient numbers to achieve efficient printing yields. Of course the operator could choose to release the queue to print at any time, at the cost of a slightly higher material waste.

Data flow rates proved to be a second challenge. Larger image files, combined with high nesting densities, can generate a lot of data during image processing and rendering. Current networks, particularly Gigabit Ethernet, can achieve the necessary data rates (in most cases). Network delays, however, can chop up the flow of the data and make it's delivery times somewhat unpredictable. The tight coupling of the printing and processing made the system intolerant of delays in printing. Unpredictable network delays during printing ended up starving the printer of data occasionally in the middle of printing. This was resolved simply with a deeper data buffer. To become completely safe from network interruptions, we ended up buffering the entire image files prior to starting printing, rather than accessing them piecemeal over the network as needed. As these buffering operations occurred concurrently with printing, there is no decrease in printing throughput.

Results and Summary of Benefits

In the final result, the production flexibility and efficiency improvements are as anticipated. In summary, the following benefits were realized:

1. Conversion from a "batch" to a "flow" process succeeded. The flexibility of this workflow allows it to replace both "roll-to-roll" and "mini-lab" style workflows.
2. Decreased labor requirements have been substantiated in by customers.
3. Color matching problems between different print sizes has been completely eliminated.
4. Calibration of multiple emulsions and printers for color match has been completely eliminated.
5. Stand alone processors and darkrooms have been completely eliminated.
6. Floor space previously taken up by additional printers, stand alone processor, darkrooms and print handling areas has been reclaimed.
7. Improved quality in B/W printing on color RA4 materials has been demonstrated.
8. Inventory management for multiple material sizes has been completely eliminated.

References

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Author Biography

Zac Bogart is President, ZBE Inc. which develops, manufactures, and markets Chromira digital printers for professional, consumer and commercial imaging applications. ZBE printers deliver the highest quality digital imaging systems capabilities at an affordable price. Graduating from University of California at Berkeley in 1980 with a B.S., Computer Engineering. Bogart formed ZBE to design special effects camera systems which were used in image-rich movies including "Star Wars" and "The Right Stuff". He refocused ZBE to image enhancement and printing. In 1998, ZBE announced the break-through Chromira digital printer line. The portfolio has achieved broad market acceptance.