Just Run It! An Experimental Evaluation of Digital Printing Performance

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Abstract

Digital color printing has had a significant impact on the commercial print market and has proven itself as a viable short-run alternative to lithography. As more digital presses move into a commercial environment, the market becomes more competitive. In many cases the print quality from digital devices is consistent; however there is variation between devices. In addition, in many cases there is not a color managed proof, hard or soft, that is used to confirm the accuracy of the print run.

This study examined the best practices needed to become an efficient and profitable digital printer in a commercial environment. It evaluated not only the productivity of the equipment, but the print quality, the manufacturing process and operations as well.

The study was carried out exclusively with commercial digital printers. The participating commercial digital printers were supplied the same print job, and through recording all steps it was possible to track this job through the entire production cycle, documenting key steps and processes. From this data it was possible to determine where the largest variations in the process were and the opportunities that arise to improve productivity.

The results presented show that there are large color deviations between the different printers, with the control on the file giving rise to gray balance issues between the presses and printers. Both RGB and CMYK separations were used and these were not handled correctly by the different workflows. The analysis of

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components within the test form also indicated significant issues with the RIPs used and these will be discussed at length.

Introduction

There has been a great change in digital printing over recent years. The companies involved in digital printing in many cases are not those that have been typically involved with traditional commercial lithography. This democratization of the market place has thrown many of the preconceived ideas with regard to the printing business away and allowed a fresh and innovative approach to the production.

The market place has become much more demanding with a different breed of customer that require printed pieces with increasingly shorter turnaround times, with several companies focusing specifically on this particular niche. These shorter production schedules and the low cost of each of the print jobs has led to in many cases little or no prepress involvement with the file. In addition, there is often no proof to compare the printed piece against.

There are many different digital presses that are available for purchase, many of which can be integrated with different digital front ends (DFEs). These create a large diversity in the number of devices that are used for printing. In addition, the devices also use proprietary inks/toners in many cases and there is very little flexibility in those that can be used. This creates a much larger range of printing combinations than is seen in commercial lithographic printing.

The objective of the investigation was to benchmark the impact of different digital printer and front end combinations on the print quality. This was achieved by providing the same files to a number of commercial printers and evaluating the prints that were returned. This provided a measure of the individual printers performance, but also the variability of the printing industry.

The job selected for this study is a two sided, four color print run which was provided in two formats, as PDF files and also as Adobe InDesign files. The user could select the files to be processed. The minimum sheet size for the job was an 11x17-inch, with a substrate basis weight between 60 lb and 100 lb. The test files have been designed to challenge the prepress workflow and identify differences in performance.

This paper will first describe the images used in the investigation and procedure for collecting the paper. This will be followed by a discussion of the results and the paper will finish with the conclusions that can be drawn from the results.

Methodology

The objective of the investigation was to evaluate the impact of different digital printer and front end combinations on the print quality. The test image was designed to qualify this based on a two sided form. The front side of the form, ***Figure 1***, contained a number of visual elements, these can best be summarized as RGB and CMYK images within the same form, fine reverse text with a drop shadow over the top, heavy coverage, a combination of color naming structures, including having spot color and CMYK simulation of the same color, varying transparency levels for spot colors. To aid with the analysis of this side of the form, a color control bar for measuring densitometric and colorimetric data was also included.

Figure 1. *Image side of test form.*

The second side of the test image was a two-page Printing Industries of America Digital Test Form 5.0, ***Figure 2***. This includes a number of items for assessment of print quality and also the DFE. Those included on the form and included in the analysis are positive and reverse text, a line resolution target, opposed line targets and the Printing Industries of America Proof Comparator that has multiple components and was used for the measurement of gray balance in the image.

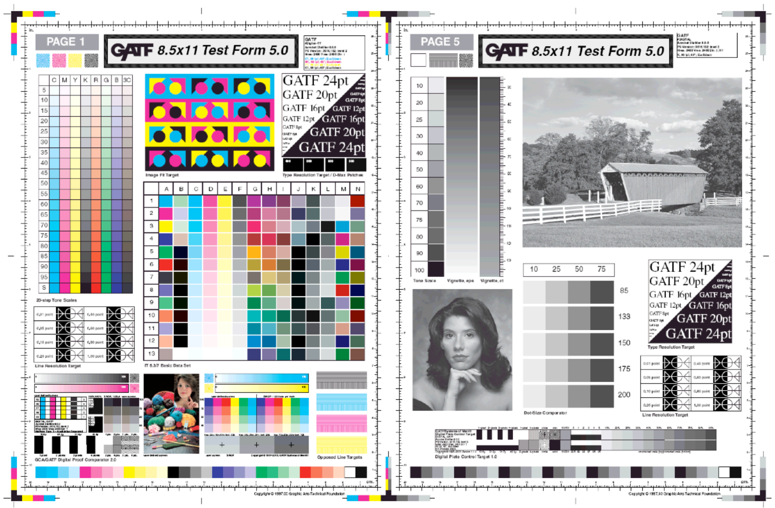

Figure 2. *Test form side of test form.*

The files were made available to the participants via and ftp site and the all the documentation and files could be downloaded. This ensured consistency of the files being delivered to the participants. The requirements for the run were the same for all participants, and these are outlined in ***Table 1***. The total run length was 100 copies, of which 50 needed to be retuned to Printing Industries of America. There was no specification on the workflow, as the aim was to evaluate the workflows and production used throughout the industry. The job was to be run in the middle of normal production, there was no proof supplied as this is often the case with short run digital production jobs. There were also no profiles embedded into the file, there was only one participant (a university) that asked where the profiles were, none of the printers requested for a profile to be supplied.

Press requirements	Any digital or inkjet press capable of producing a 4/4 job.
Screening	This is to be determined by the printer.
Paper	60lb to 100lb. C2S #1 or #2 grade, any finish.
Job sequence	Sandwich the benchmarking job between live jobs or insert as the final job of a shift. No cold start.
Color OK:	No proof is supplied. The goal is to meet a print specification in noted or pleasing color.
Total run length	100 good sheets to be produced.

Table 1. *Specifications for the print run.*

A questionnaire was developed to firstly document the company profile and then the equipment that was used to produce the job in both the prepress and pressroom. To evaluate the productivity, the times to perform each step through production were broken down by task in the questionnaire. These times covered from insertion of the loading of the files to end of the production run. The participants were asked to accurately document all steps in the process. Finally, there were questions related to the general waste numbers and process controls that were used by the printers.

Results and Discussion

The questionnaire asked about the demographics of each company, the equipment used, the targets applied and productivity data. This, in combination with the analysis of the printed sheets was used to assess the state of digital printing. The results in the paper will first cover some of the printer equipment and production data, to be followed by the analysis of the printed sheets.

Evaluating the target to which the companies were producing their prints, ***Figure 3***, all of the companies a target, with nearly 20% of those using multiple different matches dependent on the customer. The largest section that printers were required to match to was classified as other, at approximately 40% of the respondents. This category can be divided into two main classifications, as specified by the comments provided by the participants. These were to supply a proof from the press being used for the print run or to produce pleasing color. Of the remainder, more than 20% would match a proof or sample provided by the customer, while approximately 25% would print to industry guidelines. The requirements to match to a lithographic proof were the lowest of the entire different match types provided.

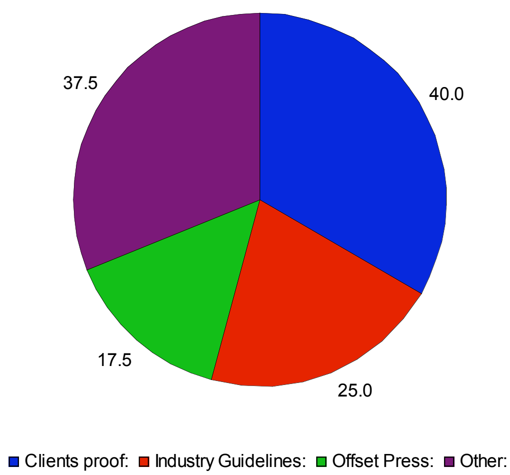

Figure 3. *Typical match requested from the clients for each of the companies.*

There were eight different press types used in the investigation, ***Figure 4***. The most widely used press was the Xerox DocuColor series which included 25% of those participating, with the other major presses represented in the study being the Xerox iGen3 and Kodak NexPress.

The calibration of the press is one of the main control features within the production environment. There are different recommendations and standards set by both the press manufactures and then implemented by the printers. The frequency of calibration was evaluated, ***Figure 5***, and this showed that in certain cases there was a large time interval between consecutive press calibrations. The majority of the participants calibrated on a daily basis, when there was a significant difference in the papers being printed or when there was a color critical production run being completed.

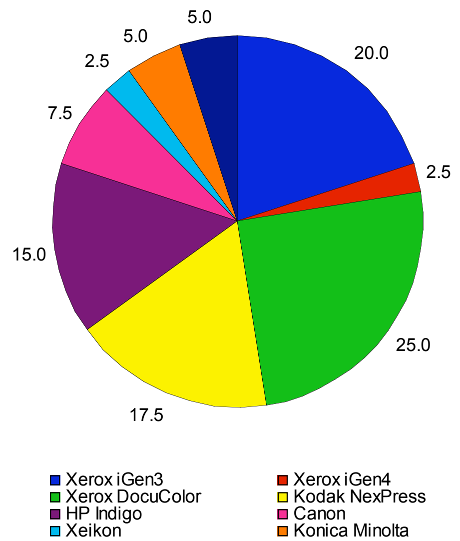

Figure 4. *Brand/ type of digital presses participating in the study.*

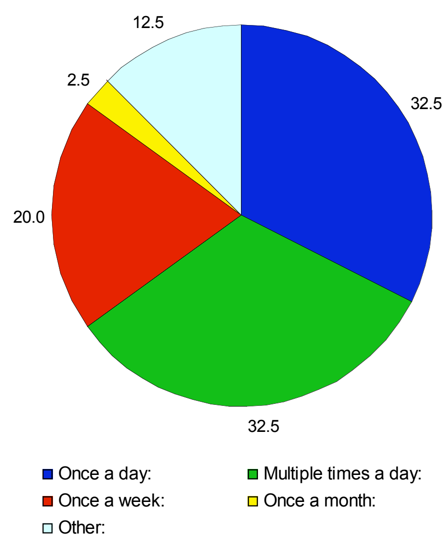

Figure 5. *How often is the digital press calibrated?*

The time for production was measured from the start of the process when the files were loaded through to the final print was produced. There was little time differences between the printers for the actual print production, with the majority of the variability occurring during the imposition of the files and then any subsequent repair that was carried out.

In prepress, the analyses focused upon preflighting and file repair, RIP and trap, imposing, and any additional time spent processing the files. In these subcategories it was shown that the average time to prefight a file was approximately 4 minutes, ***Figure 6***. The top 25% preflighted and repaired any issues in 2 minutes while those in the bottom quartile took a minimum of 5 minutes with one participant taking almost 15 minutes. Ripping and trapping the supplied files took 2 minutes on average with the top performers completing this task in less than a minute. File imposition was one of those tasks that were either not required or required a small amount of time to complete. This was clearly workflow specific. Of those that had to impose the file, it took on average 30 seconds.

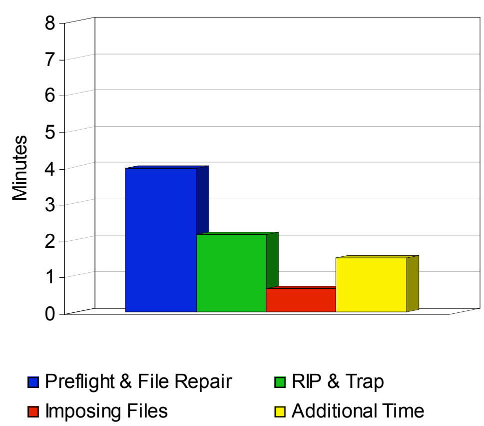

Figure 6. *Time spent processing files through prepress.*

Productivity of a digital press is extremely important as to the viability of the equipment, but if quality is not there the product becomes unsellable. Print quality is defined in this analysis as not only the color reproduction characteristics such as density, tone reproduction, and gray balance, but by the resolution of imagery such as text, line reproduction, and the capabilities of processing complex elements like native postscript.

Solid ink density measurements taken from the print samples confirm that not all presses printed to the same solid density levels. These measurements were taken from the front side of the test form from the color control bar. Results show the average values to be black 1.79, cyan 1.43, magenta 1.46, and yellow 0.97, ***Figure** 7*. These values are very typical of what an offset press would be run to. However the range in solid ink density shows that these values differed greatly.

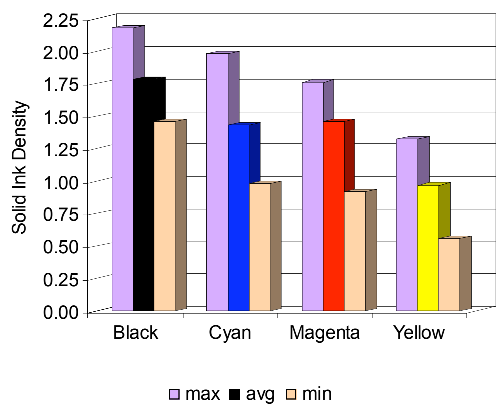

***Figure 7.** Solid ink density.*

The overall appearance of the supplied samples ranged from over saturated to very light. This was very clear from the initial visual inspection of the supplied prints. This variation was reflected in the range of density measurements, ***Figure** 7*. The average black had a range of 0.72 density units, cyan had 1.00 density units, magenta had 0.84 density units, and yellow had 0.76 density units. Density differences of greater than 0.10 density units have been shown in the past to produce significant color differences, especially when evaluating multi-color builds.

In addition to measuring solid ink density, CIE Lab measurements of the solids were also measured. The values from these measurements are shown as the median of all participating samples, ***Table 2***. The variation of the samples is shown as the ΔE_{ab} of the median value to half the range. Large differences were particularly evident for both the magenta and yellow colors.

	K	C	M	Y
L*	13.57	53.02	48.48	88.33
a*	0.42	–32.10	74.66	–7.34
b*	0.84	–51.06	–5.65	90.45
ΔE_{ab} of median to range	8.4	14.8	24.4	24.7

Table 2. *Median CIE Lab solid primary color values.*

CIE Lab measurements of the three-color builds, ***Figure 2***, that should produce a neutral gray were taken to determine if the printing presses were setup to print under a neutral condition or if a color cast was present. These measurements were taken from the back side of the test form in the area identified as the proof comparator. The three-color builds to produce a gray were made up of the following builds: 25% gray (25% cyan, 16% magenta, 16% yellow), 50% gray (50% cyan, 39% magenta, 39% yellow), and 75% gray (75% cyan, 63% magenta, 63% yellow). If color casting was measured, the CIE Lab information provides for the description of the color deviation away from gray.

Based on the average, all three simulated tonal values were considered to have a bluish/green cast. The bluish/green cast was anticipated for the reason that the three-color builds to produce the gray are based in the proof comparator target are based on the values cyan 50% and magenta and yellow 39% and modern papers with optical brighteners that traditionally produced this cast. This was identified by the negative a* and b* values, Figure 8. The maximum values documented from these measurements show a more reddish/yellow shade.

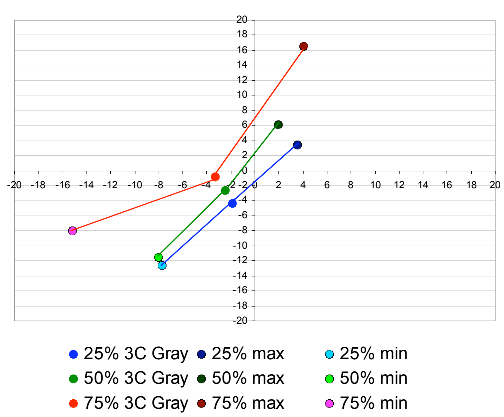

Figure 8 CIE Lab a* and b* values of the 25%, 50%, and 75%

The minimum values of the gray simulations were bluish/green in shade, much more so than the average. The 75% simulation had the most significant color shift of the minimum values as this color had an a* value approaching -16. The 25% and 50% minimum values were not as green as the minimum 75% value, but were more blue in shade noted by the -11 b* value. These differences are all visually noticeable.

Measurements of the L* values show that in analyzing these results it can be shown that the total range of the 25% simulation spanned a total of 14 L* units, Figure 29. The 50% simulation had a larger range in L* as these samples had a difference of 21 L* units. The simulated gray with the largest range in the L* values was the 75% simulation. This value had a total range of 28 L* units.

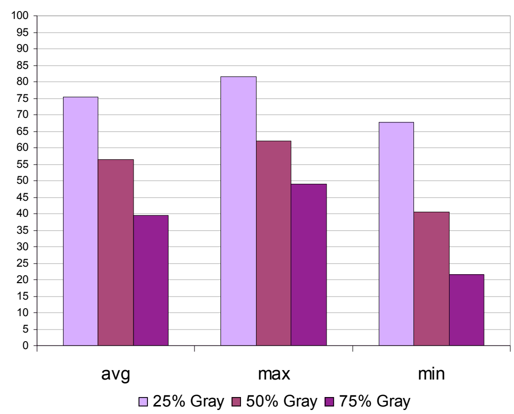

Figure 9. *CIE Lab L* values of the 25%, 50%, and 75%.*

To illustrate the color difference between prints the CIE Lab values of the maximum and minimum were used to calculate ΔE_{ab}. The ΔE_{ab} values calculated from the median and half the range produced ΔE_{ab} values that show the gray patches are not a close match when comparing specific samples, ***Table 3***. The 25% gray was the most consistent; the ΔE_{ab} was large and visually noticeable. As the screen percentage increased, the ΔE_{ab} values increased and the color differences became more significant. The results show that there are large variations in the color consistency coming from digital print devices when accepting customer files. These differences were much larger than those measured in analysis of sheetfed printers provided the same file to reproduce.

	25% Gray	50% Gray	75% Gray
L*	75.34	56.84	39.98
a*	–1.93	–2.40	–3.25
b*	–4.16	–3.56	–2.26
ΔE_{ab} of Median to range	12.0	14.7	20.8

Table 3. *Median CIE Lab values of 3-color gray.*

The line resolution target, ***Figure 2***, is a series of thin lines ranging in thickness from 0.01pt to 1.00pt. These lines are positioned horizontally, vertically, diagonally, and spherically in both negative and positive orientations. The primary objective of this target is to determine the line rendering limitations of an imaging system. A skilled observer performed the analysis visually using a loupe to inspect the line quality and define which smallest point size was rendered correctly.

The positive line target was in all cases reproduced with improved resolution, when compared to the negative line target. When analyzing the negative lines, ***Figure 10***, the majority of presses first rendered a clean discernable line at 0.40 points. Approximately 32% of the presses rendered a negative 0.20 point line cleanly, which was below the average. The thinnest negative line rendered was a 0.01 point line, which was done so by 10% of the printers. Another 12.5% were able to render a 0.10 point line. Those presses that were not able to render a line thickness of 0.40 points or less constituted approximately 2.5% of the participants.

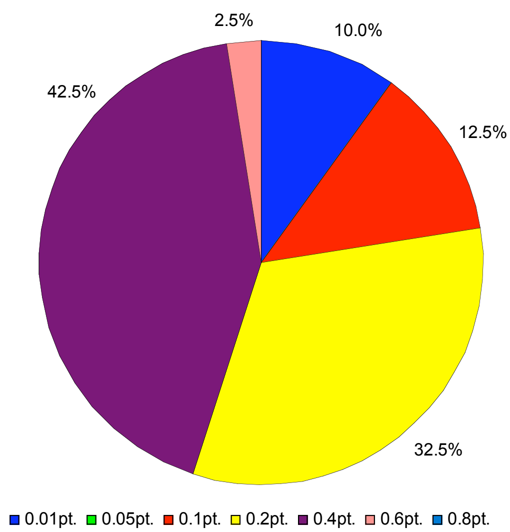

Figure 10. *Negative line resolution.*

The opposed line target was one of the more difficult items to reproduce correctly and from the analysis, the opposing line targets were identified as being imaged correctly, being banded, have imaged the lines at an angle, or have imaged the blocks as solid colors. In the analysis of these targets, if identified as being defective the results can show the sample to have multiple defects.

Only 30% of participating presses rendered the opposing line targets correctly, ***Figure 11***. Thirty percent of the participants rendered the horizontal lines, vertical lines, or both in an angular pattern. The angular pattern is compounded by the screen angles, dot shape, and the imaging system's process, which has been derived from the DFE as it renders the postscript information. Twenty five percent had banding of the horizontal lines, vertical lines, or both. Banding of this target is typically caused by a resolution incompatibility issue, indicating that the resolution of the RIP does not match the resolution of the marking engine. There are other factors that can cause banding, but the resolution incompatibility is typically the problem. In certain cases the banding only occurred with specific colors. The colors banded were not the same for all printers or digital presses.

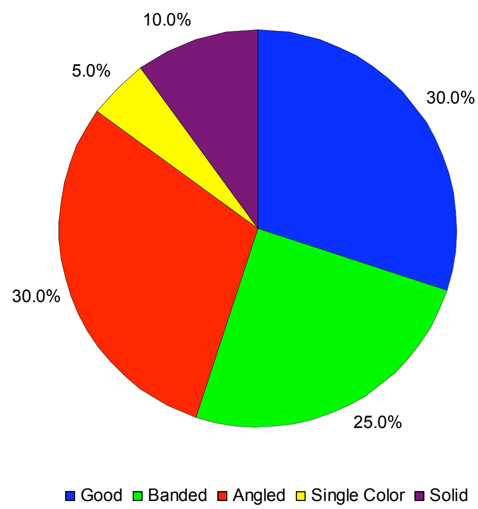

Figure 11. *Opposed line target.*

Conclusions

This digital benchmarking study has evaluated a large number of different print operations and shown that there are significant differences in both the quality and productivity from these facilities. There was no correlation between production speed and quality. The study evaluated printers of varying size, from those under $5 million to those in excess of $50 million. The majority of the participants used the PDF files; those that did not stated that this was to allow them to optimize their PDF settings. There were also a wide range of process control and quality assessments being used, with many printers targeting pleasing color.

The production time differences were primarily down to those printers that went back to the file to either correct print issues or manipulate color to obtaining the pleasing color desired. It was a minor amount of printers that carried out this step and these were all commercial lithographic printers with digital production printers.

There were significant differences in the color from both a densitometric and spectrophotometric aspect. In analyzing the three color neutral, the average of all measurements was for a blue cast, an impact of the paper coming through.

However, there were ΔE_{ab} color differences from the mean greater than 10, and between different sheets ΔE_{ab} color differences greater than 30.

The image quality showed a wide range of different quality, this was related to the set up and calibration of the printer/DFE combination and not the type of printer/DFE combination used. There were problems resolving the line targets for the majority of the participants, with banding the most common issue. When considering the opposed line targets, the best resolution of 0.40 point could only be achieved by approximately 25% of the participants.

The study provided an invaluable insight in the state of digital printing.

Acknowledgments

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