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Robert Chung

Matthew Rees

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Robert Chung

Professor, School of Print Media

Rochester Institute of Technology

Matthew Rees

Graduate Student,

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R·I·T **Printing Industry Center**
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Table of Contents

Abstract

Using an Internet-based industry survey, the differences and similarities of offset and digital print demerits within the print industry are examined. Running parallel to this examination is a look at the extent to which demerit-based quality assurance procedures exist within the printing industry. The survey findings indicate that offset and digital printing processes share common color-related print demerits. What differentiates offset print demerits from digital print demerits can be attributed to two factors: (1) technology differences and (2) printing standards. Offset printing, given the multitude of material choices, produces more frequent print demerits, relating to non-conforming materials. Digital print demerits more likely result from technical constraints such as addressability and resolution. The other factor associated is a lack of printing standards for digital printers. While both processes show a high frequency of color-related problems, offset print providers have more tools and standards available for addressing these problems. Digital print providers, on the other hand, have few color standards or tools for solving similar problems. When examining procedures for defect prevention, the general lack of digital printing standards makes the use of formal quality assurance procedures difficult. Offset print providers are more likely to have formal quality assurance procedures for dealing with frequent and severe print demerits and formal procedures for how customer quality requirements are communicated.

Introduction

The motivation to examine the differences between offset and digital print quality issues was prompted by the Government Printing Office (GPO). Within the following sections, the necessity for this examination will be explained. In addition, the two print centric models examined, offset and digital, are illustrated and discussed under the context of quality assurance.

Print-Centric Models

A print-centric production system is made up of two parts: (1) image generation sub-system and (2) imaging reproduction sub-system. In an offset print production system (Figure 1), the image generation sub-system receives print buyer's digital files. These files often require further processing to address pagination, imposition and proofing. The job is only sent to the RIP for platemaking after customer's approval. The imaging reproduction sub-system combines consumables, such as colorants and substrates, under the printing nip. In this instance, the pressman acts as the process controller. He would load paper and add ink of his or the customers choice; adjust the press settings for proper inking and image-to-image registration during the press makeready. He would pull press sheet samples, visually inspect the job for possible print defects, and measure solid ink densities from the color control bar to verify the stability of the press run. The hands-on approach of the process control eventually determines the quality of

printed job.

Figure 2 is a model that depicts a digital printing system. The image generation sub-system receives print buyer's digital files. These files may or may not require further processing to address pagination, imposition and proofing. The job is then sent to the RIP for hardcopy output. The imaging reproduction sub-system combines colorants and substrates under the imaging (electrophotographic or inkjet) nip. In this instance, the printing system acts as the process controller where all press settings and material trans-portation are handled without human intervention. The job of the press operator is to load paper and dial in the print quantity needed. The hands-off approach of the process control determines the quality of printed job.
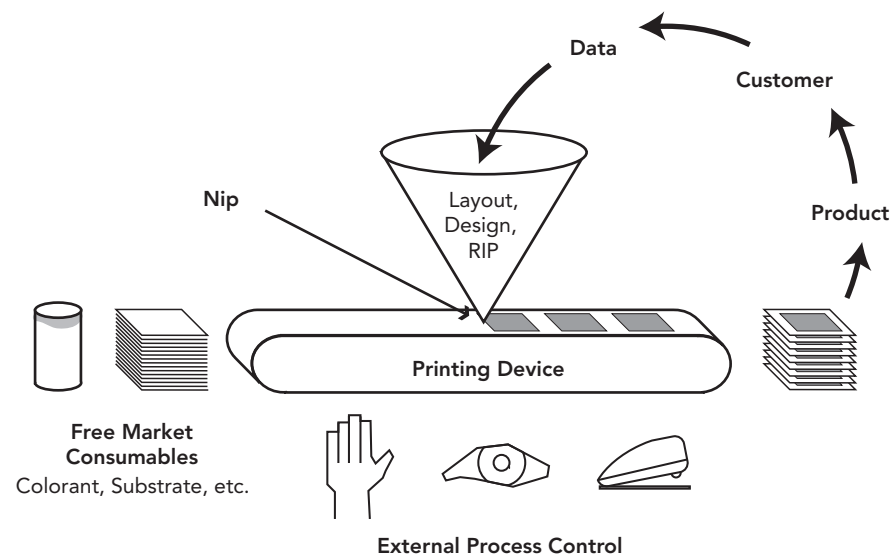

Figure 1. Offset printing system model

A fundamental difference between the two system models lies in how the process is controlled. With the offset printing system model, the print vendor purchases the print-ing devices from a technology provider and has the options to choose materials from an open market. The printer then chooses how he manages the consumables and tech-nology to ensure that they are able to turn his customer's data into a product. Process control is facilitated by the standards available to offset printers. The digital printing system model, because both the consumables and technology are married to the same proprietary provider, has a limited choice of press management options for the printer to choose from.

The other fundamental difference between the two system models is how each is utilized in fulfilling customer's printing needs. If a print buyer submits a print order for 10,000
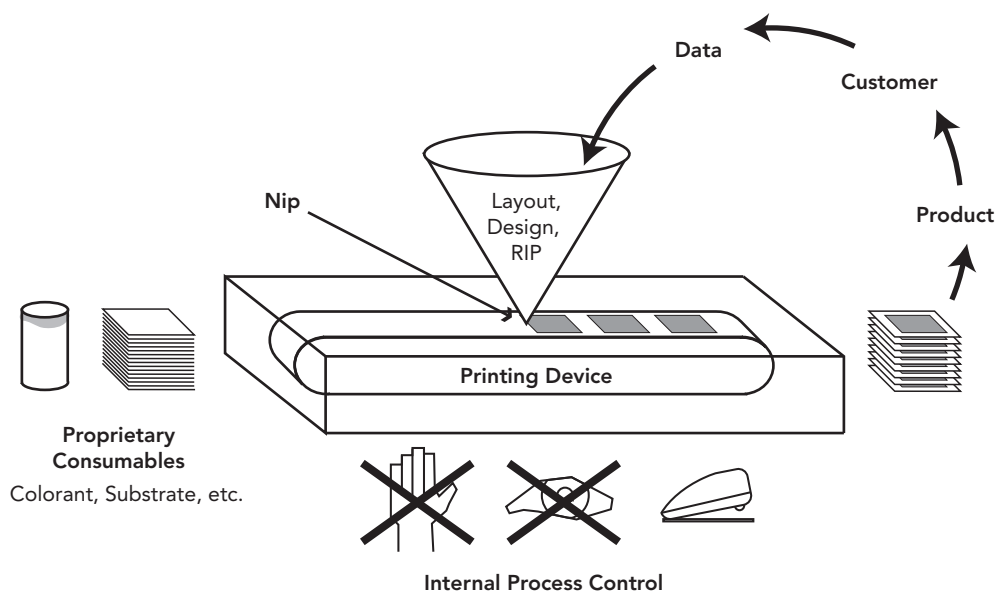
Figure 2. Digital printing system model

brochures with spot and process colors, the print vendor is likely to use offset to print the job. However, if a print buyer submits a print order for 100 flyers including variable data, the printer will use digital printing to produce the job. Thus, we anticipate a large number of survey respondents who use both offset and digital printing systems in their business.

The GPO Prompted the Survey

The 'Digital Print Quality' project was prompted by input from the Government Printing Office (GPO) when it first became an industry partner of the Printing Industry Center at the Rochester Institute of Technology in 2005. The GPO uses a quality assurance standard originally created for offset lithography when purchasing digital print. This standard, however, fails to address many of the print attributes common to digital print, such as background toning, banding, color variation, etc. As digital printing gains a larger portion of the print market share, the ability to express and quantify its quality becomes more important. Currently there are no digital printing standards for material conformance or for preventing digital defects. This is in opposition to offset printing, which has at its disposal a myriad of printing-related standards that facilitate the testing of material conformance and color reproducibility.

Objectives

Given the absence of digital standards and the growing need to objectively quantify digital print quality, a survey was conducted with the following objectives:

1. To investigate whether digital print demerits are significantly different than offset print demerits, and

2. To determine to what extent attribute-based quality practices are used in the printing industry.

Delimitations

- One time survey distributed through e-mail for a duration of two weeks.

- Population sampled consists of solely offset and digital printing companies.

- A majority of the input comes from print providers who have a relationship with the GPO.

- The focus of the survey is on the company's opinion on dealing with offset and digital print quality issues.

- Based on the literature review, little was found regarding print providers' opinions of offset and digital print quality issues.

- Based on the literature review, this is the first survey of its kind.

- The findings are based on the analysis of the survey.

Literature Review

This review of the literature surrounding offset and digital print standards and quality-based assurance practices begins with an overview of the approach of the Government Printing Office (GPO) to specifying quality requirements. The GPO is an agency within the legislative branch whose mission is to produce and distribute information products and services using both traditional and digital printing processes. Approximately 70% of the printed work it produces today is purchased from commercial sources.

Quality Assurance Through Attributes Program (QATAP)

In the late seventies, the GPO's Quality Control and Technical Department established the Quality Assurance Through Attributes Program (QATAP) to provide specifications and quality assurance procedures for its printed materials. The program divided government printing into five quality levels. At each level, the quality requirements of a contractually-printed product are clearly identified and described in terms of definable and measurable attributes (Materazzi & Meade, 1977).

The evaluation of image quality traditionally has been one of visual defect detection, as assessed by the customer. The presence or absence of undesired visual print attributes within a final product (e.g., hickies, poor text readability, excessive color variation, extraneous marks) would lead to the rejection or acceptance of a job. QATAP's model defines attributes and data collection procedures, and allows the use of a demerit system to determine if a job meets the required quality levels. In practice, a print demerit is assigned to attributes of the printed product that are inadequate, unacceptable, or which fail to meet specific requirements. The model allows print quality to be turned into numbers, which can then be used for management and control purposes.

In a paper written by Ian C. White entitled "The Print Quality Index, A Management Tool," three categories of defects are defined: minor, major and critical (White, 1975). Minor defects are slight imperfections which, if noticed, would not be the source of any complaint. A minor defect does not fall outside of any specified numerical tolerances. Major defects are defects which seriously affect the overall visual appearance of the product. Examples of these defects are hickies, streaks, and mottle. Major defects fall outside of specified tolerances. Critical defects are serious deviations from specifications which jeopardize the integrity of the product (e.g., the cover of a book tears away from the spine when it's laid flat). When the number of print demerits exceeds a specified tolerance level, particularly with critical defects, there is sufficient cause to reject the job.

Offset Print Standards

Within the offset printing field, there are various understandings on how to deal with conformance. This situation developed in part because the maturity of offset technology has resulted in the development of many standards and industry-recognized practices. As shown in Table 1, these standards and practices give the printer great control

over the measures used to prevent defects. Offset print standards also afford the printer a great deal of control over the conformance of materials before they enter the production process. These standards only fail in their ability to address the visual significance of any print defects.

Table 1. A list of applicable standards for offset lithographic printing

Material Conformance	ISO 1524	Provides procedures for measuring fineness of grind
	ISO 12644	Facilitates the measurement of viscosity
	ISO 12634	Allows for the measurement of ink tack
	ISO 2470	Enables the brightness of a substrate to be measured
	ISO 5626	Provides procedures for measuring folding endurance
	ISO 8254	Specifies how to measure the gloss of a substrate
	Ink Draw Down	Accommodates the preliminary evaluation of color properties
	ISO 2846	Specifies the color and transparency values for process colors
Process Control	ISO 12647	Defines tonal value increase and solid ink tolerances for a variety of paper grades

Digital Print Standards

Digital printing, when compared to offset printing, is a hands-off process. An offset press operator who has tested the inks and substrates can make modifications (e.g. by adding surfactants, defoamers, primers, etc., or adjusting plate pressure, press speed, ink coverage, etc.), either prior to a pressrun or on the fly, to make up for any problems that might occur on the press. On the flip side, most production digital printing processes depend on the use of certified paper to perform to their best capacity. Any adjustments that need to be made to the actual press require the intervention of technical support personnel other than the press operator.

While digital printing materials are not yet standardized, some work has been done exploring the impact that materials have on digital printing, with the intention of developing material standards. In a recent study, the print quality of digital and traditional technologies was compared subjectively and quantitatively (Norberg, Westin, & Lindberg, 2001). Two test images were printed using a variety of commercially available digital printing devices such as color copiers, ink jet printers, and liquid and toner based presses. The same two test images were also printed using flexographic and lithographic technology. The test images were produced on a variety of paper stocks ranging from uncoated to fully coated. International Color Consortium (ICC) profiles were created for each paper type and applied to each print. The results showed that offset print quality is still ahead of what is possible in digital technology, although the quality of offset printing is highly dependent on the substrate, whereas digital image quality is less dependent on the substrate. The study also exposed the two print attributes which were most influential on subjective print quality: mottle and micro gloss variation. In corresponding studies it has been verified that digital printing substrates are critical to the quality of the image; however, as stated above, there are currently no standards for testing digital printing substrates.

Regarding digital color reproduction, an article entitled "Properties of Digital Presses and Their Prints," outlines the results of a study aimed at establishing basic target values and tolerances for colorimetric and technical properties of digital presses (Traber & Gemeinhardt, 2005). The study examined properties such as digital reproducibility, registration, spatial and temporal color variation, and toner bonding, and compared them to offset print standards (ISO 12647-2). The results of this study demonstrated that many of the ISO 12647-2 tolerances could be applicable to digital print. This study and the substrate experiments of Norberg et al. (2001) indicate a change in the atmosphere surrounding the materials used in digital print—a desire to develop standard procedures for evaluating these materials. However these new experiments, like the offset standards in place, do not address the visual significance of the digital print attributes.

In 2001, a paper entitled "Evaluating the Overall Image Quality of Hardcopy Output" (Dalal et al., 1998) became one of the first articles written with regards to known digital print attributes and a proposed methodology to quantifying such attributes. This article served as a guide for the development of the first digital standard, ISO 13660. ISO 13660 is a standard for evaluating the digital image quality of black-and-white digital printing produced by office equipment, using the diagnostic metrics described earlier. In the GPO method (the Quality Assurance Through Attributes Program or QATAP), offset print attributes are compared against a spec or an OK'd print in order to assess print quality; however with digital printing, the image to be evaluated is produced directly within the digital device and therefore has no reference to which it can be compared. What ISO 13660 accomplished was to provide:

- Definitions for many print attributes,
- Bitmap test patterns, and

- A method for measuring the defined attributes.

Once these measured attribute tolerances could be set by the end user, digital print quality could be evaluated.

ISO 13660 has certain limitations and drawbacks. Being a standard for black-and-white office printers, there are no methods in place to measure color. It also fails to address many common print attributes such as banding, and does not account for the visual significance of occurring print demerits. To address these issues, a new proposed ISO standard, ISO 19751, states: "A small number of general visual attributes have been recognized as essential in describing image quality. These include micro-uniformity, macro-uniformity, color rendition, text and line quality, gloss, sharpness, and spatial adjacency or temporal adjacency attributes" (Rasmussen et al., 2004). This new standard proposes a method for quantifying the visual significance of occurring print demerits and also expands on the list and definitions of print demerits.

The available literature demonstrates that offset print attributes and the assessment of these attributes are well established. With the new activity in the development of digital printing standards, questions surrounding the differences or similarities between digital and offset attributes have arisen. Also, there is little documentation examining how customers express their print quality requirements. The objectives of this survey were to shed light into these areas.

Methodology

The GPO's need to differentiate between the print quality of offset and digital processes is clear. Instead of assuming that we have all the answers, we decided to survey the printing industry. In doing so, we were able to verify how it is coping with the same problem. The following procedures were used to design a print quality survey, implement the survey via the Internet, and analyze the data.

Survey Design

The survey was designed to collect information regarding the characteristics of each responding printing company (size, services provided, years in business, etc.), as well as the frequency and severity of digital and offset print demerits. To fulfill the research objectives, questions were also asked regarding how customers express quality requirements and how those requirements are fulfilled. A certain element of flexibility was added to the survey by allowing respondents to provided open-ended answers to questions. A complete copy of the survey can be found in Appendix A.

Print Demerit Definitions

As illustrated in the literature review, the GPO's QATAP, ISO 13660 and the proposed

ISO 19751 all provide concrete definitions for many print attributes. It is from these documents that a set of print attributes and their definitions were derived. The focus of the survey is such that the definitions of the derived print attributes were rewritten to spotlight the visual aspects of a print attribute as opposed to the quantifiable characteristics. The print attributes and definitions chosen for this survey are as follows:

- **Banding** - A breakup of a smooth blend into stair-steps in a gradient; also known as false contour; one dimensional, periodic lightness and/or chromatic variation.

- **Color cast** - An overall tendency within an image toward a hue direction; the most noticeable area of color cast is in neutrals and near-neutrals in a color image.

- **Color non-uniformity** - Subjective impression of color constancy of lightness, hue, saturation across a large area of a single print.

- **Color variation** - Subjective impression of color constancy of lightness, hue, saturation from multiple printed sheets.

- **Ghosting** - Heavy removal of ink or toner, by other areas on the printed page resulting in starvation of ink or toner in other areas of the printed image.

- **Graininess** - A non-uniform sand like or granular appearance within the imagery of a printed product

- **Hickies** - Spots or imperfections on the printed image that can be traced to dust, dry ink skin, paper particles, ink splatter, etc

- **Mis-registration** - Misalignment of one printed element to another, typically this refers to how precise one printed element overlays another printed element with the same dimension

- **Moiré** - An objectionable interference pattern caused by the out-of-register overlap of two or more regular halftone dot or line patterns.

- **Mottle** - Uneven appearance of a uniformly printed area which may be caused by uneven inking or uneven adherence of ink on substrate; variation in density, typically defined as large, low frequency variations in solid areas

- **Poor line quality** - Inability to resolve fine lines due to either addressability or resolution limitation.

- **Poor trapping** - Lack of overprinting of a narrow strip of one color over the other at their junction

- **Poor text quality** - Lack of quality of the text, (serifs, thin strokes versus thick strokes), variation in type density.

Survey Distribution

With the support of various entities, we e-mailed over 3,000 print providers, inviting

them to take our survey online using SurveyMonkey.com. The communication provided information regarding the nature of the research and also enticed the print providers to respond by offering them the opportunity to enter a drawing for an Apple iPod™. Using the Internet as the medium by which data would be collected allowed for a great amount of versatility to be built into the survey. Such versatility allowed respondents, based on their responses, to be steered toward questions which would yield the most relevant information. Additionally, accessing the survey online allowed participants the freedom to take the survey at their own leisure, which may have contributed to the strong response.

Data Analysis and Reporting

As seen in Figure 3, the data analysis is handled in three Tiers. Tier 1 represents the overall data analyzed from all 279 respondents in terms of pros and cons between offset and digital printing. Since the goal of the survey is to investigate whether there are real print quality differences between offset and digital printing, Tier 2 represents a smaller data set, 157, from respondents who use both offset and digital printing in their businesses. Tier 3 represents the smallest data set, 47, that was further "filtered" whereby respondents also have formal quality assurance practices. We expect more signals and less noise in the data analysis as we move from Tier 1 to Tier 3.
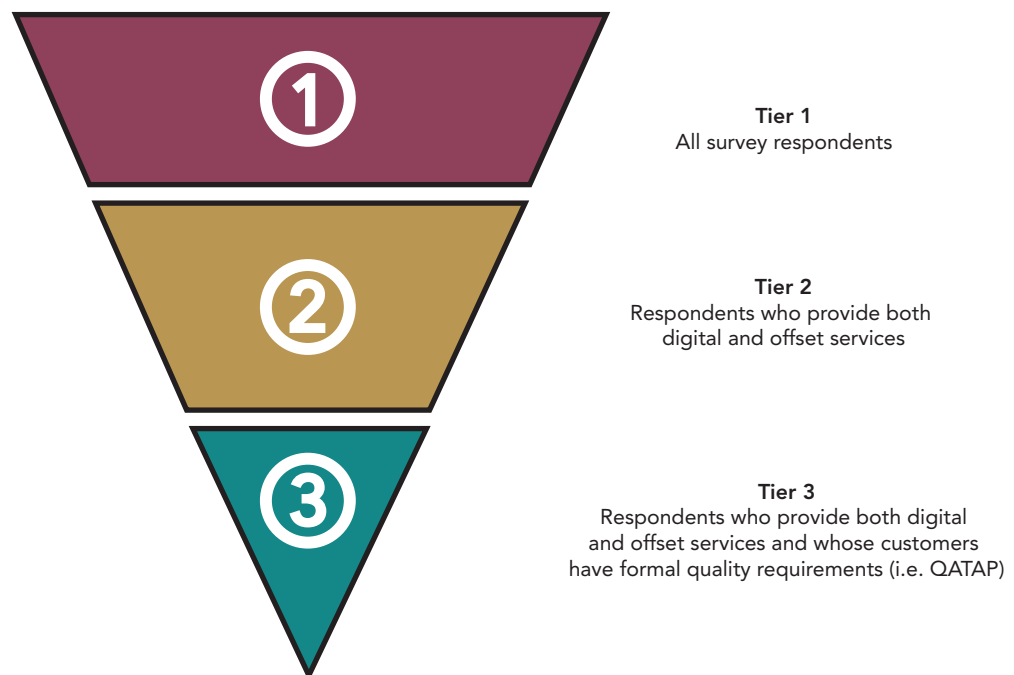

Tier 1
All survey respondents

Tier 2
Respondents who provide both digital and offset services

Tier 3
Respondents who provide both digital and offset services and whose customers have formal quality requirements (i.e. QATAP)

Figure 3. Three tiers of data analysis

Results

The online survey was launched on October 9, 2006, and was active for two weeks. The survey was distributed to over 3,000 contacts. Within those two weeks, 279 individuals responded to the survey, with 87% of those responses occurring within the first two days. At the close of the survey, the gathered data was complied and analyzed. The following charts provide an aerial perspective of the population of respondents.

Tier 1: Survey Respondents as a Whole

The first question asked respondents to indicate which type of service they provided: offset, digital, or both. As shown in Figure 4, 157 (56%) of respondents offered both services, 75 (27%) offered only offset services, and 47 (17%) offered only digital services.
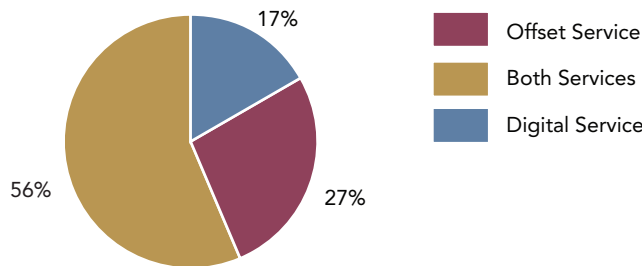
Figure 4. Services provided by respondents

Respondents were asked to indicate how many years they had been providing print services. For example, a 4 color printing press has four printing units. As shown in Figure 5, the majority of respondents had been providing offset for more than 20 years. In contrast, the majority of those providing digital services had only been doing so for the last 1 to 10 years.
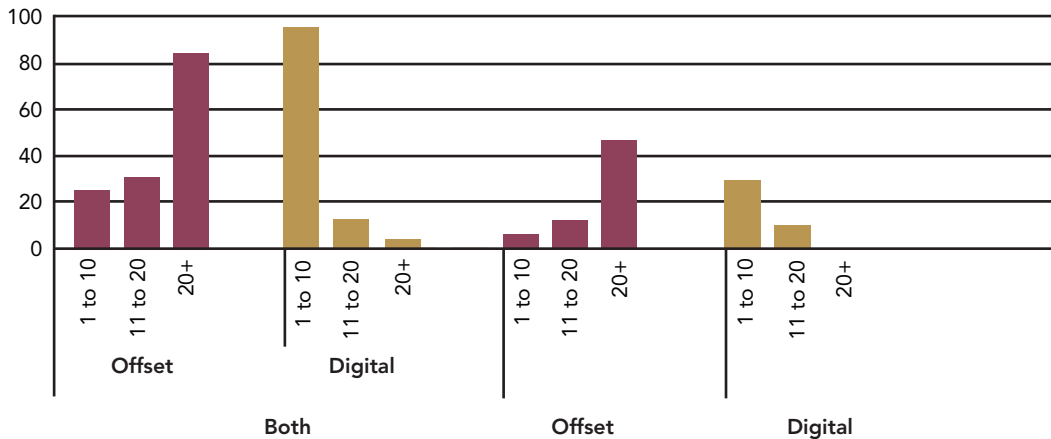
Figure 5. Years providing print services

To gain information regarding the size of the company, respondents were asked the total number of printing units, by service, within their company. The assumption is that; the more printing units within a company, the larger the company. As shown in Figure 6, a majority of companies have 1-10 printing units, while a minority has over 30 printing units. The majority of companies which provided digital services had 1-10 printing units, while a small number had 11 to 20. There were no companies which had more than 20 digital printing units.
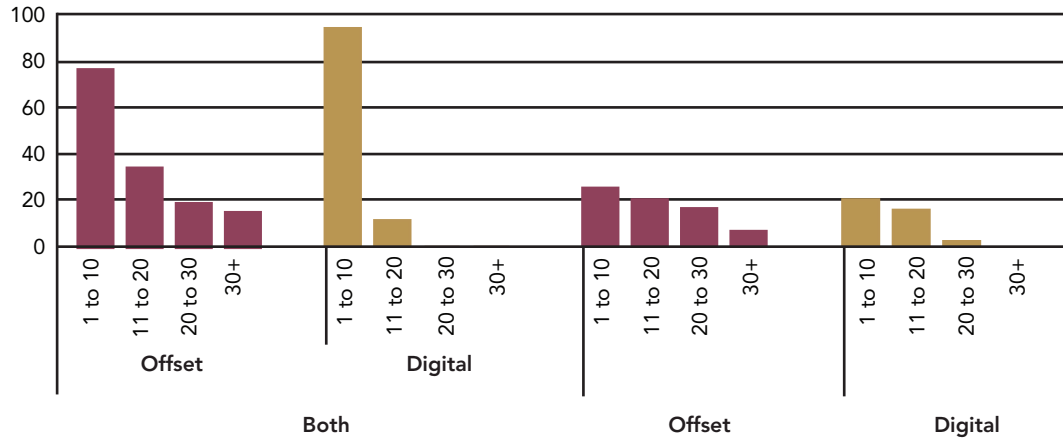
Figure 6. Size of company by number of printing units

Overall Frequency and Severity of Print Demerits

Respondents were asked to rate the frequency and severity which they experience print demerits on a scale of 1 to 5, where '1' indicates low frequency or severity and '5' indicate high frequency or severity. As seen in Figure 7, 84% of offset providers indicated that the frequency of print demerits occur at a low rate (1 or 2 on a 1 thru 5 scale). 74% of the digital respondents signified that the frequency of print demerits is low.
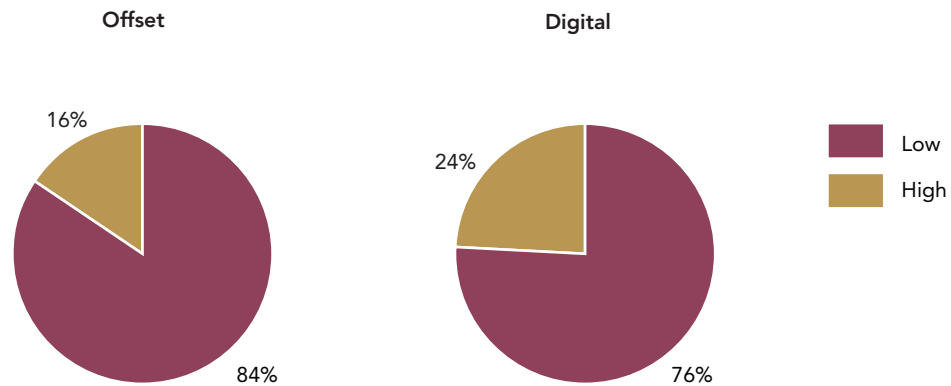
Figure 7. Frequency of print demerits based on all respondents

Figure 8 illustrates that, 87% indicated that the severity of offset print demerits which occur is low, while 76% of digital providers indicated that the severity of occurring print demerits is low.

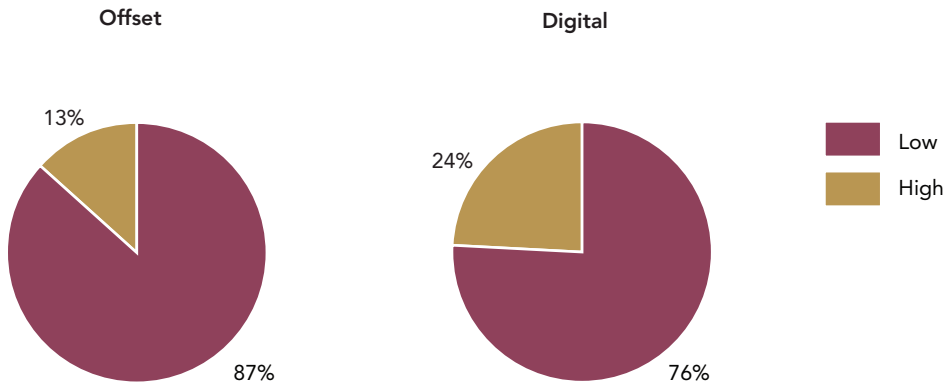**Offset**   **Digital**

13%

24%

Low

High

87%   76%

Figure 8. Severity of print demerits based on all respondents

We used the following weighting function to calculate a weighted sum: Where N is the weighted sum with 'A' indicating the number of responses indicating the lowest frequency or severity and 'E' indicating the highest frequency or severity.

$$N = 1A + 2B + 3C + 4D + 5E$$

The highest-ranking demerits for both frequency and severity were identified. As seen in Figure 9, hickies were found to be the most frequent offset print demerit, followed by color variation and color non-uniformity. Color variation was noted as being the most frequent digital print demerit followed by banding and color non-uniformity.
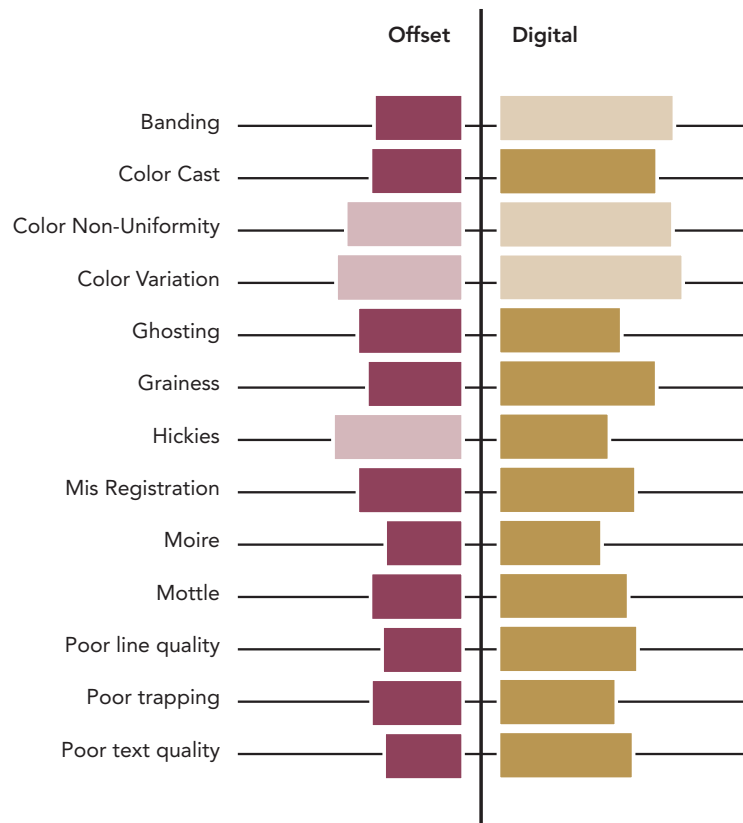
Figure 9. Overall print demerits by frequency

The same three offset print demerits indicated as the most frequent, seen in Figure 9, were found to also have the most severe effect on print quality. Instances of banding, seen in Figure 10, had the most severe impact on digital image quality followed by color non-uniformity and color cast.

Overall Customer Quality Requirements

Respondents to the survey were asked to indicate how customers were expressing quality requirements. As seen in Figure 11, offset print providers responded that 43% of their customers never express any quality requirements. 30% indicated that quality requirements are expressed, however there is no documentation of those expressed requirements. 27% indicated that customers were using formal quality requirement procedure such as the GPO's QATAP. Digital services providers followed similar suit as offset print providers with regards to how customers are expressing quality requirements. Shown also in Figure 11, 43%of digital print providers indicated that no quality requirements are expressed. 39%, slightly larger than offset providers, indicated that quality requirements are expressed, however nothing is documented and 18% indicated that there is a formal quality procedure.
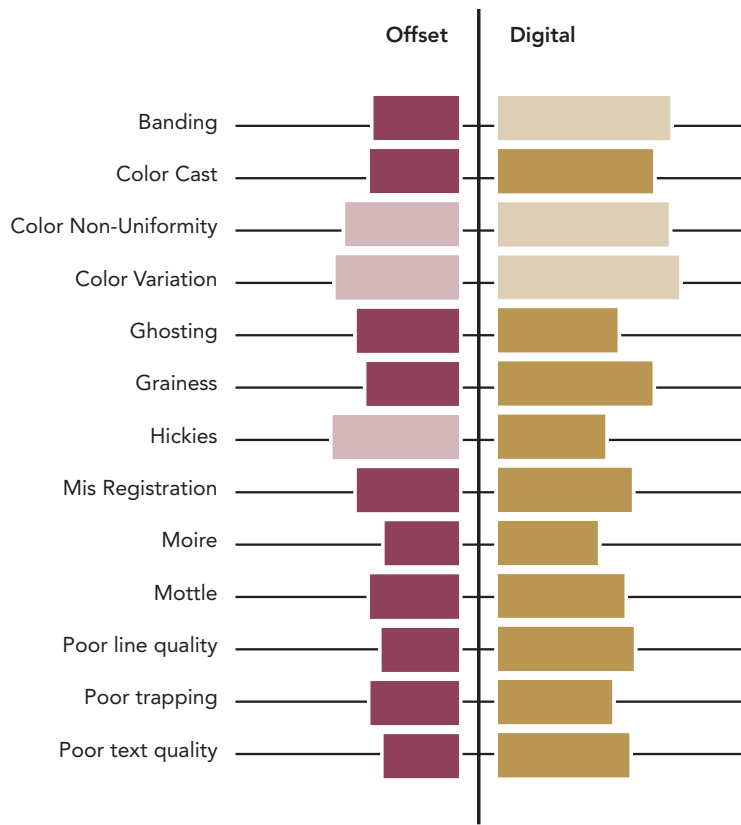
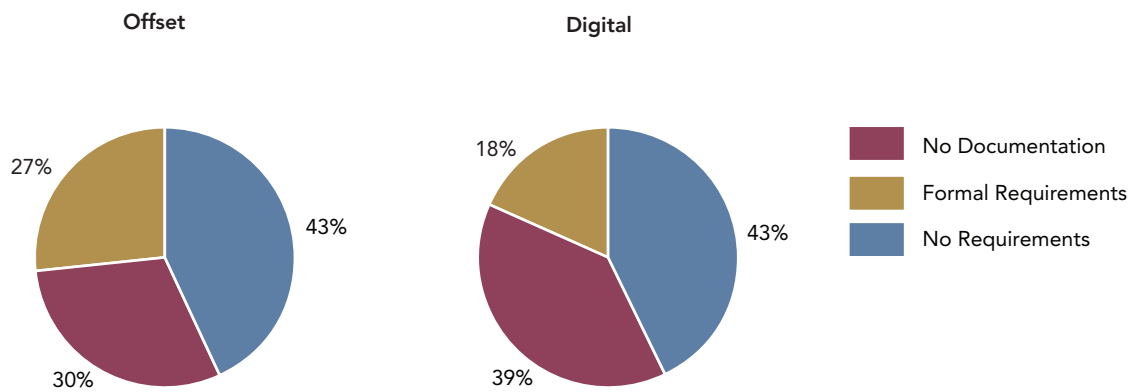Figure 10. Overall print demerits by severity

Figure 11. How quality requirements are expressed

Overall Handling of Frequent and Severe Print Demerits

Respondents were then asked to identify how print demerits which are frequent or sever are handled. As determined from the data gathered and as shown in Figure 12, 69% indicated that they experimented to resolve problems. The next 30% indicated that print demerit issues were addressed with either the technology providers or the consumable providers, and the remaining 1% of offset providers signified that nothing was done about frequent or severe print demerits. For digital processes, 59% noted that print demerit issues were addressed with either the technology providers or the consumable providers, 35% purported that they experimented to find solutions and 6% of digital providers communicated that nothing was done about print demerits that were deemed frequent or severe.

Offset

Digital

1%

6%

30%

59%

69%

35%

■ Issue is adressed with vendor

■ Experiment to solve problem

■ No action taken
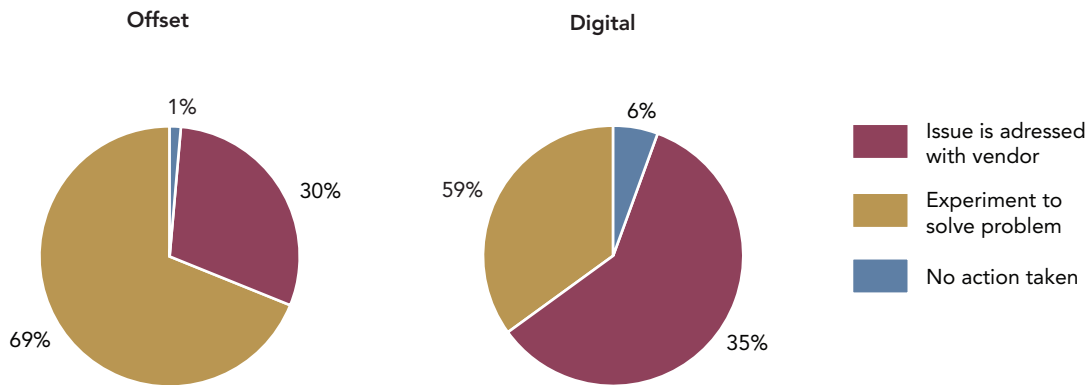
Figure 12. How frequent or severe print demerits are handled

Discussion

Many companies indicated that given the advancements made in workflow and imaging technology, frequent and severe print demerits which occurred prior to the introduction of computer aided workflows has significantly been reduced. As a result, a large majority of print providers (84% of offset providers and 76% of digital providers) responded that attribute related print problems are either non existent or occur at a low frequency. The following is a typical response "These (print demerits) were trouble we had up until the 1990s. With computers and workflow being used, demerits are low in frequency and severity..." Overall, the differences between the frequency and severity of offset and digital print demerits indicate that offset providers struggle with print demerits which may have more to do with the consumable materials involved with the production process (i.e. hickies as a result of substrate quality) where as digital print providers struggle with the limitations of the process (i.e. non-uniformity as a function of unevenly distributed electromagnetic charges). Each process, offset and digital, share similar color related print attributes, such as color variation and color non-uniformity.

Tier 2: Respondents Who Provide Both Digital and Offset Services

Of the 279 respondents to the survey, 157 offer both offset and digital services. This portion of those sampled represents Tier 2 of our analysis. The practices of companies that offer both services are of significance to this current body of research because they offer insights into the differences and similarities of offset and digital processes, as seen by companies that run them side-by-side on a regular basis.

Frequency and Severity of Print Demerits in Companies That Offer Both Offset & Digital Services

Respondents in this category were asked to rate the frequency and severity in which they experience print demerits on a scale of 1 to 5, where '1' indicates low frequency or severity and '5' indicates high frequency or severity. In addition to asking respondents to rank the frequency and severity of print demerits, the survey also asked them to indicate how quality requirements were being expressed by customers and how print demerits that were deemed frequent or severe were being handled.

As seen in Figure 13, the majority of the Tier 2 respondents indicated there were low frequencies as far as encountering print demerits. Specifically, 86% of Tier 2 respondents indicated a low frequency in offset demerits and 78% indicated low digital print demerits.
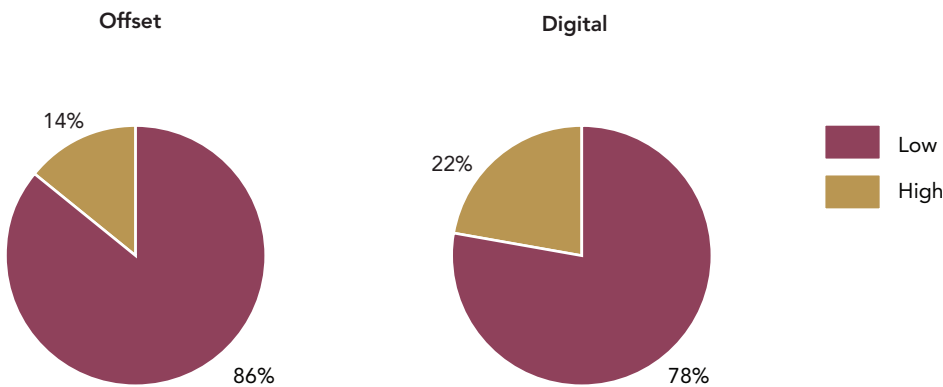

Figure 13. Frequency of print demerits in Tier 2 respondents

A smaller section of the Tier 2 respondents indicated there were high frequencies of print demerits. In this case, 14% of Tier 2 respondents indicated high frequencies in offset demerits and 22% indicated high digital print demerits.

Figure 14 illustrates the severity of offset and digital print demerits by providers who offer both services. 91% of Tier 2 companies indicated that they experience a low sever-

ity of offset print demerits, 9% indicated a moderate to high severity. 78% of Tier 2 companies also indicated that the severity of digital print demerits was low., while 22% told us that digital print demerits occurred with moderate to high severity.
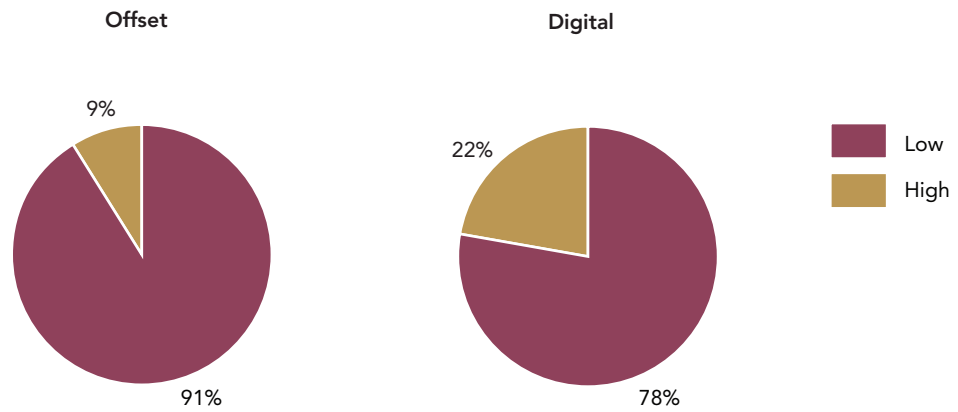
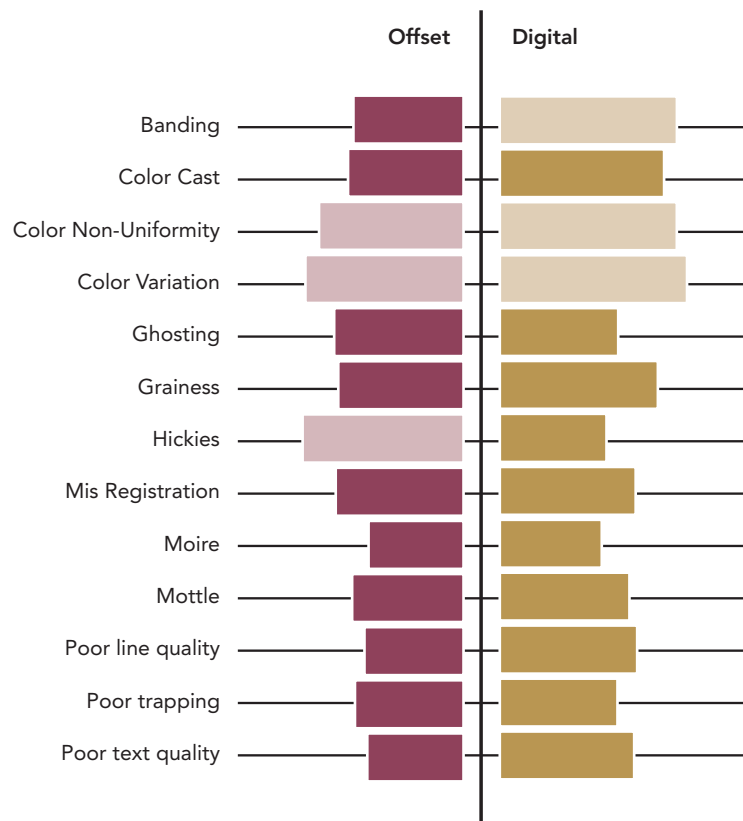Figure 14. Severity of print demerits in Tier 2 respondents

Figure 15. Print demerits by frequency

In Tier 2 companies, the offset print demerit which occurred most frequently was the problem of hickies, followed by color variation and color non-uniformity. (See Figure 15.) The three most frequent digital print demerits exhibited by Tier 2 companies were color variation, color non-uniformity and banding.
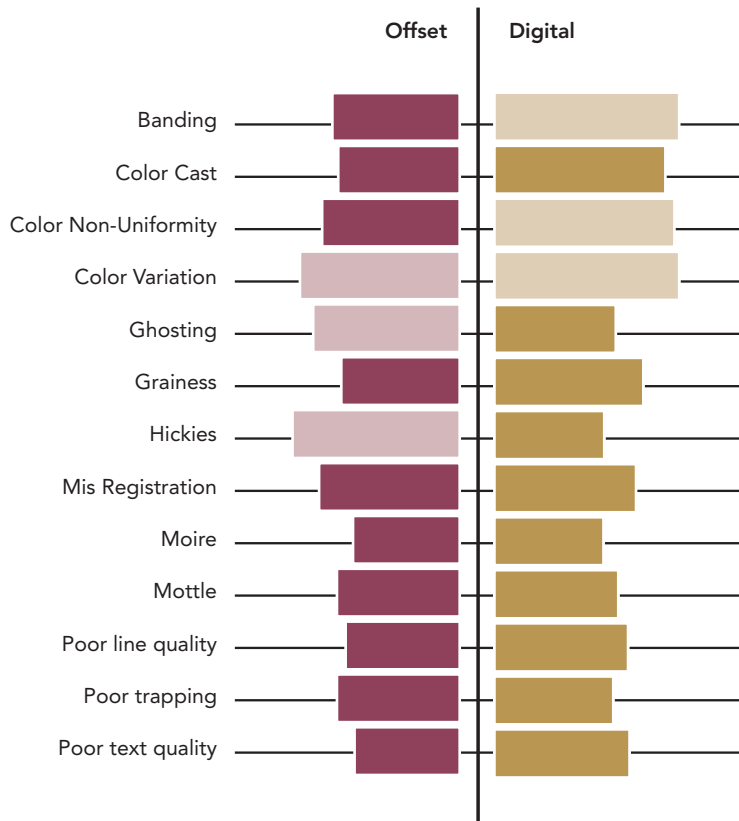
Figure 16. Print demerits by severity

With regards to offset print demerits which cause the most severe print problems, hickies and color variation were the top two offending print demerits, followed by ghosting. This is shown in Figure 16. The digital print demerits of color variation, banding and color non-uniformity had the most detrimental impact on image quality.

Customer Quality Requirements in Companies That Offer Both Offset & Digital Services

As shown in Figure 17, when we examined how customers and companies express and communicate quality requirements, we found that 47% of Tier 2 companies disclosed that their customers do not express offset quality requirements. Another 30% of these companies had customers whose quality requirements were expressed but not documented, and the remaining 23% used a formal quality procedure program such as the QATAP. When compared to the digital side of their business, also shown in Figure 17, 44% of Tier 2 companies indicated that customers of their digital services do not express quality requirements. 38% of the companies had customers who discussed quality requirements, but did not document them, and the remaining 18% have formal quality requirements. Within this group of respondents we see that digital quality requirements are discussed more frequently than offset quality requirements; however there are fewer instances of formal quality procedures.
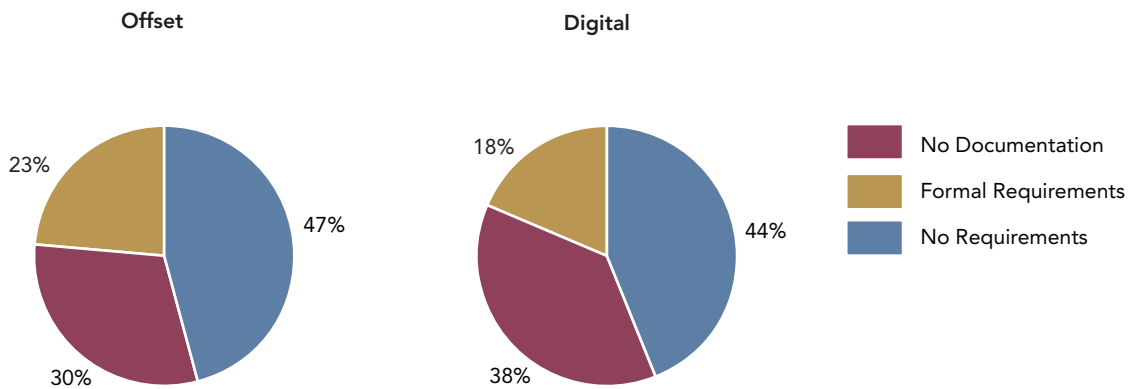
Offset

Digital

23%

47%

30%

18%

44%

38%

No Documentation

Formal Requirements

No Requirements

Figure 17. How quality requirements are being expressed

The Handling of Frequent or Severe Print Demerits by Companies That Offer Both Offset & Digital Services

When asked to indicate how frequent or severe print demerits are handled, companies offering both offset and digital services responded in a similar fashion as the offset print providers we surveyed. Seen in Figure 18, for offset problems, 68% experiment on their own, 31% take issue the consumable provider and 1% of these companies do nothing. For digital problems, 59% take issue with the consumable or technology provider, 33% experiment on their own, and 8% do nothing with digital demerits which are deemed frequent or severe.
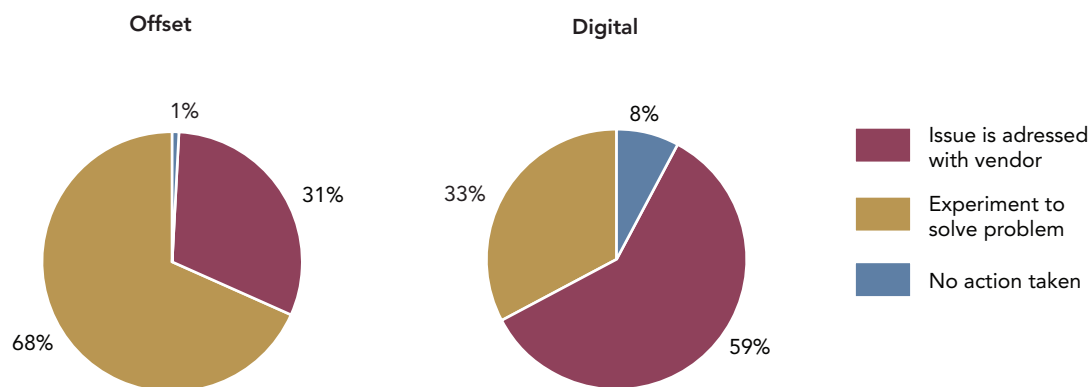
Offset   Digital

1%   8%

31%   33%   Issue is adressed with vendor

68%   59%   Experiment to solve problem

No action taken

Figure 18. How print demerits which are deemed frequent or severe are handled

Discussion

The occurrence of offset print demerits within Tier 2 companies is nearly identical when compared to the responses from all offset providers, however only 9% of companies that offer both services indicated severe problems associated with print demerits as compared to 13% of the offset print providers. Respondents who offer both services also shared the top three ranking offset print demerits with the offset print providers in the survey, these being hickies, color variation and color non-uniformity. Companies that chose to provide open-ended comments stated that substrate problems (such as variations within a paper's coating, issues with lightweight stocks, or the common misperception by customers that high-quality reproductions can occur on low-quality stocks) had a large impact on image quality. What should be noted is that color variation, color non-uniformity, and mottle can all be side effects of non-conforming or ill-suited substrates.

The frequency and severity of digital print demerits found in Tier 2 companies is nearly identical to the larger population of digital print providers we surveyed. The top-offending print demerits were very similar: both groups (companies who offer both services and those who were strictly digital providers) ranked color variation and color non-uniformity in the top three. Digital print providers also had color cast as one of their top three offending print demerits, whereas companies which offer both services had banding as their third top offending print demerit.

The high ranking of digital color-related print demerit problems was further substantiated in a review of the open-ended comments. A large portion of these comments focused on color issues which appeared to result from the immaturity of digital color technology. These color issues revolved around difficulty in matching colors and noticeable patterns in large flat tinted areas. Comments regarding the lack of stock versatility, stock curl, and gloss variation within the substrate were also present. Many digital print providers also indicated that workflow problems occur frequently, such as truncated paragraphs, data that is present in the file not printing or RIPping, and front-to-back

mis-registration. No comments were made regarding whether these issues were a result of the RIPping process or whether they arose from supporting print software or hardware.

Tier 3: Respondents Who Provide Both Digital and Offset Services and Who Have Formal Customer Quality Requirements

Tier 3 companies are broken down into two sub groups. A company's placement into one subgroup or the other is determined by how its customers communicate print quality requirements. Companies that responded to the survey were asked to indicate how their customers communicated print quality requirements from three choices, as follows:

1. There is no requirement communicated until after the fact.

2. Print demerits are discussed, but not documented.

3. There is a formal quality assurance program, e.g., GPO's QATAP.

For the sake of simplification, these responses will be given the title Customer Quality Levels (CQLs). Response one, indicating no quality requirements are communicated until after the fact, is Customer Quality Level 1 (CQL 1). Response two, indicating that print demerits are discussed, but not documented, is Customer Quality Level 2 (CQL 2). Those companies who chose response three, indicating that a formal quality assurance program does exist within their companies, were assigned a Customer Quality Level 3 (CQL 3).

The first subgroup was composed of companies that indicated that customers communicate requirements using CQLs 1 & 2. The second subgroup was composed of companies that signified that customers communicate requirements using CQL 3. The results of those companies which have CQLs 1 & 2 were analyzed, followed by companies which have CQL 3. Then these two subgroups were compared to see whether there are real differences in offset versus digital print demerits.

Figure 19 illustrates the frequency of offset print demerits for both CQL 1&2 companies and CQL 3 companies. The differences between the two are miniscule. Jumping ahead in the analysis and looking at Figure 23, what is shown is that the top three most frequently occurring offset print demerits for CQL 1&2 and CQL 3 companies are identical. Overall, when looking at the frequency and severity of print demerits between CQL 1&2 companies versus CQL 3 companies, it was found that having a formal procedure in place for expressing quality did not have an impact on the frequency or severity of print demerits. Nor did formal quality procedures play a role in which print demerits occurred. Both CQL 1&2 companies and CQL 3 companies responded along parallel lines with regards to the frequency and severity of offset and digital print demerits., thus filtering the Tier 3 companies by customer quality assurance requirements did

not produce a greater signal to noise ratio, with regards to the frequency and severity of print demerits. Most CQL 1&2 and CQL 3 companies are not experiencing frequent or severe print demerits, but when they do, there is no difference in the type of print demerit experienced.

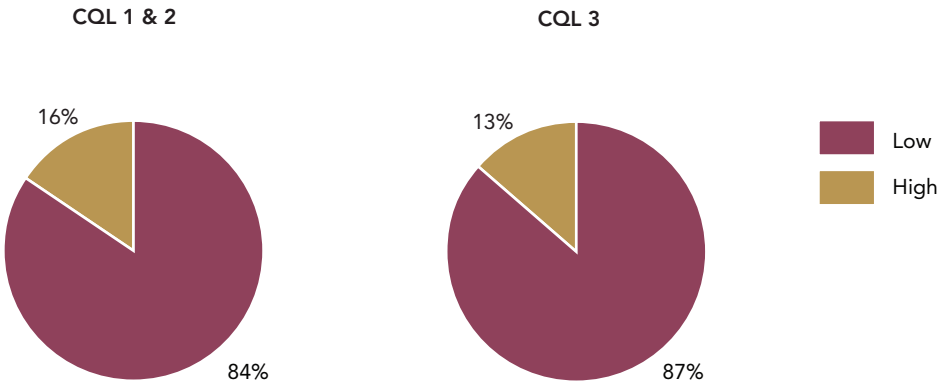As such, Figures 19-26 are placed in Appendix B.

CQL 1 & 2

CQL 3

16%

13%

84%

87%

Low

High

Figure 19. The frequency of offset print demerits for CQL 1 & 2 vs. 3

CQL 1 & 2 | **CQL 3**

Banding
Color Cast
Color Non-Uniformity
Color Variation
Ghosting
Grainess
Hickies
Mis Registration
Moire
Mottle
Poor line quality
Poor trapping
Poor text quality
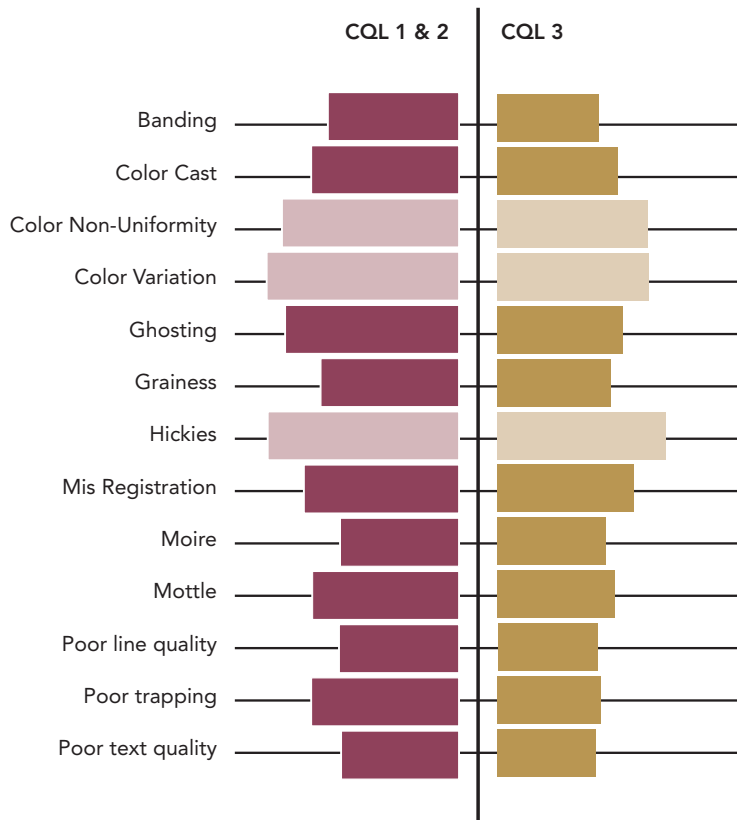
Figure 23. Offset print demerits by frequency for CQL 1 & 2 vs. CQL 3 companies

Tier 2 Versus Tier 3 Companies

While a company's customer quality requirements, either informal or formal, had no effect on the nature of occurring print demerits, the response to occurring print demerits was notably different. As seen in Figure 27, when asked how their companies handle offset print demerits which are deemed frequent or severe, 59% take issue with the technology or consumables provider, 40% experiment on their own to find solutions to such offset print demerit and 1% of the CQL 1 & 2 companies responded that they do nothing. On the other hand, 67% experiment on their own to resolve issues, 33% take their offset print demerit issues to the technology or consumables provider, and there wasn't a single CQL 3 company that took no action against frequent or severe offset print demerits.
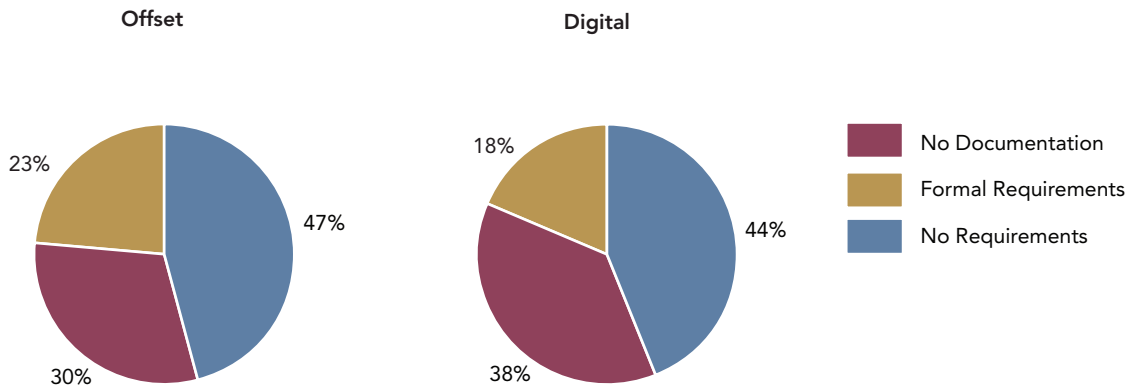
Figure 27. How offset print demerits in companies with CQL 1 & 2 vs. CQL 3 are handled
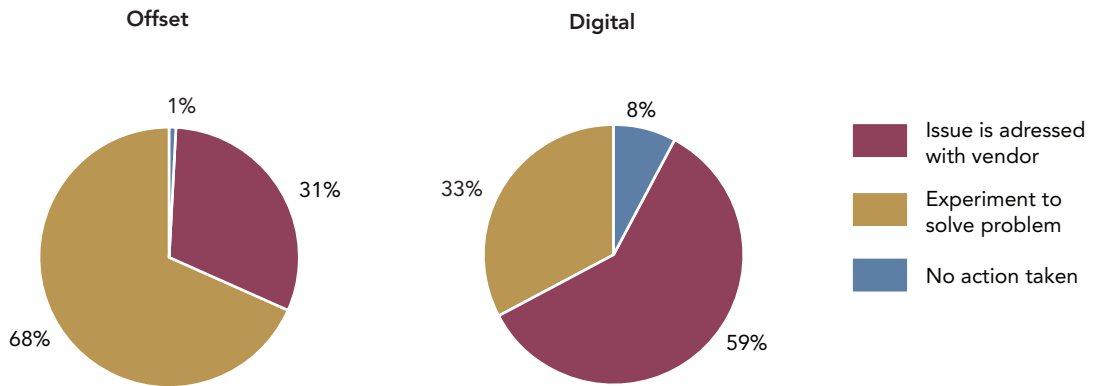
Figure 28. How digital print demerits in companies with CQL 1 & 2 vs. CQL 3 are handled

As seen in Figure 28, 76% take issue with the technology and consumables provider, 18% experiment on their own to find solutions and 6% of the CQL 1 & 2 companies we surveyed do nothing when digital demerits are found to be frequent or severe. For the CQL 3 companies, 50% take their issues to the technology and consumables provider, 43% experiment on their own to resolve issues and 7% take no action when it comes to dealing with frequent or severe digital print demerits.

Discussion

Print Demerits

There is little difference between companies whose customers have no formal quality requirements (CQL 1 & 2) and from those who have formal quality requirements (CQL 3), with regards to the frequency and severity of print demerits. Similarly, there is little difference in the top three offending print demerits. Color issues such as color variation and color non-uniformity are consistently ranked as the top print demerits for both frequency and severity. Color related print demerits also extend equally into each printing process. Offset and digital printing process share reoccurring color problems.

In examining the print demerit differences within CQL 3, companies when comparing offset to digital, what can be seen is that the ranking of print demerits directly correlates to the print process. For example, offset printing is able to resolve and address a much finer dot. The result is that addressability based print demerits (Poor line quality, poor text quality and banding) are ranked lower than digital printing. What is also seen is that high ranking digital demerits such as (banding, graininess, variation in large flat tints) appear to be attributed to the inherent variations with the technology, such as variations in electrostatic charges and with the workflow, such as digital file input problems.

Regardless of the CQL or printing process the foundation of a quality print is in part built from the customer supplied files. From the open ended responses, a typical comment relating to this issue was that "Usually the only problem with bad copy is what the customer has supplied to us and they know in bad out bad". In once case, a company made mention that issues such as banding within their output could be attributed to the files provided by the customer.

Handling of Print Demerits: Formal vs. Non Formal Quality Requirements

As seen from the data gathered a large percentage of offset printers experiment to resolve frequent or sever print demerits on their own. This is reflected in the open ended responses. The predominant comments throughout the responses indicate that those who are experimenting to resolve issue are doing so under an ISO or internal QA system. CQL 3 companies are more likely to have well defined SOP's, are more likely to supply vendors with material specs, are more likely to monitor and measure their own process and are more likely to hold routine reviews of internal procedures. CQL 1 & 2 printers are much more likely to address problems with a vendor and less likely to

experiment on their own to resolve issues, when compared to CQL 3 printers. Digital printers, as shown in the charts, follow the same suit with a greater percentage of CQL 3 printers experimenting to resolve issues when compared to CQL 1 & 2 printers. Formal QA procedures do not indicate that less problems occur, but indicate that time is saved by self experimentation.

Within the open ended responses, two comments were made which couldn't be categorized into a group (i.e., color comments, substrate comments, workflow comments, etc) which were unique to digital printing. The first comment was that the company's down time on digital presses was greater than down time on offset presses. The second comment, as one printer put it, was that "from a quality assurance point of view, the process is never in control. We have to look at every sheet." These two side comments stand out as being by-products of the closed system in which digital printing currently functions. Down time is greater due to the necessity of resolving issues with proprietary vendors. Quality initiatives are more difficult because the entire process cannot be examined to determine if it is under control. In this closed system, incoming materials are delivered by the technology and consumables providers with no standards in place to ensure conformance. While the variability of the output can be determined through color measurements, gloss measurements, etc., the options for controlling the output variability is limited because the "hands-off" nature of the process. Process changes within the digital system have to be initiated by the operator of the digital press and, if substantial changes are required, need to be carried out by the press manufacturer.

Conclusions

The data gathered from the survey paints a picture depicting the occurrence of print defects, the relationships customers and their print providers have with regards to print quality, and the print defects which are the most problematic. The key findings of the survey can be summarized as such:

- Of the 3,000 invitations we sent out to companies for this survey, 279 responses were received, a 9.3% response rate.

- The majority of the respondents (84% of the offset and 76% of the digital printing providers) indicated that the frequency of print demerits they experience is low.

- Of the 279 respondents, 157 (56%) offer both offset and digital services.

- Less than 25% of the respondents using both digital and offset processes indicated that their customer quality requirements are documented.

- Color variation and color non-uniformity were found consistently to be in the top three most frequently occurring print demerits in both offset and digital printing processes.

- Print providers who offer both digital and offset processes and whose customers have formal quality requirements tend to solve print quality problems by experimenting on their own. Those print providers whose customers do not have formal quality requirements tend to take print quality related problems to their vendors.

- Overall, when looking at the frequency and severity of print demerits between companies which don't have formal quality requirements versus companies which do have formal quality requirements, it was found that having a formal procedure in place for expressing quality did not have an impact on the frequency or severity of print demerits. Nor did formal quality procedures play a role in which print demerits occurred.

- There is a correlation between the frequency and severity of the top three offending print demerits. Those print demerits which occurred most frequently, also were the cause of the most severe print defects.

- The root causes of print demerits are:

    1) The open-system nature of offset printing technology. That is, print demerits are often the result of incompatible consumables, such as paper grades.

    2) The closed-system nature of the digital printing technology. Digital print demerits are often the result of the workflow (including customer-submitted files, the RIP, etc.), or the inherent noise of the digital printing engine (spatial non-uniformity and temporal consistency, etc.).

The data shows that the top-ranking print demerits afflicting both offset and digital print providers are color-related. What is unknown, however, is the nature of these frequent and severe color print demerits. Are color-related problems arising because industry standards for color tolerances are too low when compared to customer expectations? Are print providers measuring their color variation?

What has been established through this survey is that the majority of color-related problems found within offset printing can be attributed to the materials involved in producing the printed product, whereas with digital print, color-related demerits appear to stem from the inherent constraints of the technology. Since the offset printing industry has already at its disposal the tools for measuring and monitoring color-related print demerits, the path forward needs focus on how digital technology providers can address color-related print problems within their own proprietary devices. In addition, the path forward will also need to focus on what the printing industry as a whole will do to bring about standards and procedures for monitoring and measuring color within the digital printing environment.

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Appendix A:
Survey Tools

Objective

Conducted by the Rochester Institute of Technology's School of Print Media, in association with the RIT Printing Industry Center, the objective of this survey is to investigate

1. whether digital print defects or demerits are significantly different from offset printed demerits, and
2. to what extent demerit-based quality assurance practices are used in the printing industry.

We are requesting 10 minutes of your time to answer a few questions regarding printing technologies used in your company, print demerits encountered (as shown below), and your company's quality assurance practices for digital and offset printing operations. Individual data will be treated with strict confidence; only summary data will be used for reporting and publication. This survey is open October 9 - 23, 2006.

Print Demerits

Banding	Graininess	Mottle
Color cast	Hickies	Poor line quality
Color non-uniformity	Mis-registration	Poor trapping
Color variation	Moire	Poor text quality
Ghosting		

Win an iPod!

Upon completion of the survey, qualified respondants may enter a drawing to win an **Apple® iPod™ 30GB MP3 and Video Player**. The drawing will be held on **October 30, 2006**, to select the winner from all qualified entries. The winner will be contacted using an email address requested in the survey.

Questions

Questions regarding this survey may be directed to:

Bob Chung, Professor, RIT
phone: 585.475.2722
email: rycppr@rit.edu

Matthew Rees, Graduate Student, RIT
phone: 585.298.4381
email: mjr9967@rit.edu

Thank you for your participation!

Please indicate the services that your company offers:

○ *Both* OFFSET and DIGITAL printing services

○ *Only* OFFSET printing services

○ *Only* DIGITAL printing services

○ Neither

Part 1. About Your Company's OFFSET Printing Capabilities and Products

What is the total number of OFFSET printing units in your company? (e.g. one 4-color press has 4 printing units)

◯ 0   ◯ 1 < 10 units   ◯ 10 < 20 units   ◯ 20 < 30 units   ◯ 30 or more units

How many years has your company provided OFFSET printed products?

[   ]

What is the average run length for your company's OFFSET jobs?

[   ]

Part 2. Regarding OFFSET Print Demerits and Quality Assurance Practices

This section includes questions regarding OFFSET print demerits, which are defined below.

Print Demerit Definitions

Print defects or demerits are described here. Please review these definitions before answering the following set of questions.

Banding A breakup of a smooth blend into stair-steps in a gradient; also known as false contour; one dimensional, periodic lightness and/or chromatic variation.

Color cast An overall tendency within an image toward a hue direction; the most noticeable area of color cast is in neutrals and near-neutrals in a color image.

Color non-uniformity Subjective impression of color constancy of lightness, hue, saturation across a large area of a single print.

Color variation Subjective impression of color constancy of lightness, hue, saturation from multiple printed sheets.

Ghosting Heavy removal of ink or toner, by other areas on the printed page resulting in starvation of ink or toner in other areas of the printed image.

Graininess A non-uniform sand like or granular appearance within the imagery of a printed product.

Hickies Spots or imperfections on the printed image that can be traced to dust, dry ink skin, paper particles, ink splatter, etc.

Mis-registration Mis-alignment of one printed element to another, typically this refers to how precise one printed element overlays another printed element with the same dimension.

Moiré An objectionable interference pattern caused by the out-of-register overlap of two or more regular halftone dot or line patterns.

Mottle Uneven appearance of a uniformly printed area which may be caused by uneven inking or uneven adherence of ink on substrate; variation in density, typically defined as large, low frequency variations in solid areas.

Poor line quality Inability to resolve fine lines due to either addressability or resolution limitation.

Poor trapping Lack of overprinting of a narrow strip of one color over the other at their junction.

Poor text quality Lack of quality of the text, (serifs, thin strokes vs thick strokes), variation in type density.

Part 2. Regarding Offset Print Demerits and Quality Assurance Practices (co...

Rank the following 13 print demerits in terms of the FREQUENCY in which your company typically encounters in its OFFSET printing.

	1 = Low Frequency	2	3	4	5 = High Frequency
Banding	◯	◯	◯	◯	◯
Color cast	◯	◯	◯	◯	◯
color non- uniformity	◯	◯	◯	◯	◯
Color variation	◯	◯	◯	◯	◯
Ghosting	◯	◯	◯	◯	◯
Graininess	◯	◯	◯	◯	◯
Hickies	◯	◯	◯	◯	◯
Mis-registration	◯	◯	◯	◯	◯
Moiré	◯	◯	◯	◯	◯
Mottle	◯	◯	◯	◯	◯
Poor line quality	◯	◯	◯	◯	◯
Poor trapping	◯	◯	◯	◯	◯
Poor text quality	◯	◯	◯	◯	◯

Rank the following 13 print demerits in terms of the SEVERITY in which your company typically encounters in its OFFSET printing.

	1 = Low Severity	2	3	4	5 = High Severity
Banding	◯	◯	◯	◯	◯
Color cast	◯	◯	◯	◯	◯
color non- uniformity	◯	◯	◯	◯	◯
Color variation	◯	◯	◯	◯	◯
Ghosting	◯	◯	◯	◯	◯

Graininess	○	○	○	○	○
Hickies	○	○	○	○	○
Mis-registration	○	○	○	○	○
Moiré	○	○	○	○	○
Mottle	○	○	○	○	○
Poor line quality	○	○	○	○	○
Poor trapping	○	○	○	○	○
Poor text quality	○	○	○	○	○

Did we leave any important OFFSET print demerits out?

Part 2. Regarding Offset Print Demerits and Quality Assurance Practices (co...

How do your major customers communicate OFFSET print quality requirements to you?

○ There is no requirement communicated until after the fact

○ Print demerits are discussed, but not documented

○ There is a formal quality assurance program, e.g., GPO's QATAP

What do you do about OFFSET print demerits that are deemed freqent and are severe to your print quality?

○ Nothing

○ Take the issue up with the vendors

○ Experiment to resolve demerits on my own

○ Other (please specify)

Part 3. About Your Company's DIGITAL Printing Capabilities and Products

What is the total number of DIGITAL printing units in your company? (e.g. one 4-color press has 4 printing units)

◯ 0   ◯ 1 < 10 units   ◯ 10 < 20 units   ◯ 20 < 30 units   ◯ 30 or more units

How many years has your company provided DIGITAL printed products?

[   ]

What is the average run length for your company's DIGITAL jobs?

[   ]

Part 4. Regarding DIGITAL Print Demerits and Quality Assurance Practices

This section includes questions regarding DIGITAL print demerits, which are defined below.

Print Demerit Definitions

Print defects or demerits are described here. Please review these definitions before answering the following set of questions.

Banding A breakup of a smooth blend into stair-steps in a gradient; also known as false contour; one dimensional, periodic lightness and/or chromatic variation.

Color cast An overall tendency within an image toward a hue direction; the most noticeable area of color cast is in neutrals and near-neutrals in a color image.

Color non-uniformity Subjective impression of color constancy of lightness, hue, saturation across a large area of a single print.

Color variation Subjective impression of color constancy of lightness, hue, saturation from multiple printed sheets.

Ghosting Heavy removal of ink or toner, by other areas on the printed page resulting in starvation of ink or toner in other areas of the printed image.

Graininess A non-uniform sand like or granular appearance within the imagery of a printed product.

Hickies Spots or imperfections on the printed image that can be traced to dust, dry ink skin, paper particles, ink splatter, etc.

Mis-registration Mis-alignment of one printed element to another, typically this refers to how precise one printed element overlays another printed element with the same dimension.

Moiré An objectionable interference pattern caused by the out-of-register overlap of two or more regular halftone dot or line patterns.

Mottle Uneven appearance of a uniformly printed area which may be caused by uneven inking or uneven adherence of ink on substrate; variation in density, typically defined as large, low frequency variations in solid areas.

Poor line quality Inability to resolve fine lines due to either addressability or resolution limitation.

Poor trapping Lack of overprinting of a narrow strip of one color over the other at their junction.

Poor text quality Lack of quality of the text, (serifs, thin strokes vs thick strokes), variation in type density.

Part 4. Regarding Digital Print Demerits and Quality Assurance Practices (c...

Rank the following 13 print demerits in terms of the FREQUENCY in which your company typically encounters in its DIGITAL printing.

	1 = Low Frequency	2	3	4	5 = High Frequency
Banding	○	○	○	○	○
Color cast	○	○	○	○	○
color non- uniformity	○	○	○	○	○
Color variation	○	○	○	○	○
Ghosting	○	○	○	○	○
Graininess	○	○	○	○	○
Hickies	○	○	○	○	○
Mis-registration	○	○	○	○	○
Moiré	○	○	○	○	○
Mottle	○	○	○	○	○
Poor line quality	○	○	○	○	○
Poor trapping	○	○	○	○	○
Poor text quality	○	○	○	○	○

Rank the following 13 print demerits in terms of the SEVERITY in which your company typically encounters in its DIGITAL printing.

	1 = Low Severity	2	3	4	5 = High Severity
Banding	○	○	○	○	○
Color cast	○	○	○	○	○
color non- uniformity	○	○	○	○	○
Color variation	○	○	○	○	○
Ghosting	○	○	○	○	○

Graininess	○	○	○	○	○
Hickies	○	○	○	○	○
Mis-registration	○	○	○	○	○
Moiré	○	○	○	○	○
Mottle	○	○	○	○	○
Poor line quality	○	○	○	○	○
Poor trapping	○	○	○	○	○
Poor text quality	○	○	○	○	○

Did we leave any important DIGITAL print demerits out?

[text box]

Part 4. Regarding Digital Print Demerits and Quality Assurance Practices (c...

How do your major customers communicate DIGITAL print quality requirements to you?

○ There is no requirement communicated until after the fact

○ Print demerits are discussed, but not documented

○ There is a formal quality assurance program, e.g., GPO's QATAP

What do you do about DIGITAL print demerits that are deemed freqent and are severe to your print quality?

○ Nothing

○ Take the issue up with the vendors

○ Experiment to resolve demerits on my own

○ Other (please specify)

[text box]

Part 5. Products Printed

For each product type listed, please indicate whether your company prints a lot, prints occasionally, or not at all.

	Prints A Lot	Prints Occasionally	Not At All
Informational (periodicals, books, annual reports, legal)	○	○	○
Promotional (catalogs, advertising, direct marketing)	○	○	○
Packaging (labels, packaging)	○	○	○
Product (stationary, wrapping paper, forms, greeting cards)	○	○	○

Copy of the Survey and Enter for a Chance to with an iPod

Would you like to receive a copy of the results of this survey?

○ Yes

○ No

Would you like to enter the drawing for a chance to win an Apple iPod (30GB MP3 and Video Player)? *The winner will be selected on October 30, 2006, from all qualified and successful survey respondants.*

○ Yes

○ No

Enter Your Contact Information

Please provide us with your contact information so that we may provide you with a copy of the survey results and/or enter you into the drawing for an iPod.

Please provide us with your contact information.

Name	
Company	
Title	
Phone Number	
Email Address	

Thank you for your responses!

Thank you for completing our survey! Your responses will be anonymously compiled and reported in a research monograph to be published with the RIT Printing Industry Center.

Select SUBMIT below to submit your responses.

Appendix B:
Further Analysis of Print Demerits

Figures 19 thru 26 compare the responses of CQL 1 & 2 companies versus the responses of CQL 3 companies. It was found that both groups of companies responded similarly with regards to the frequency and severity of print demerits, regardless of quality requirements. Since there was little difference between the frequency or severity of occurring demerits and the type of print demerits which was occurring, this information has been moved to the appendix. The following presents a complete analysis of Figures 19 thru 26.

Figure 19 illustrates the frequency of offset print demerits for companies with CQLs 1 & 2 versus those with CQL 3. 84% of CQL 1 & 2 companies indicated that the frequency of offset print demerits was low, and 87% of CQL 3 companies indicated that offset print demerits occurred with a low frequency. In other words, both groups were virtually the same.

CQL 1 & 2   CQL 3

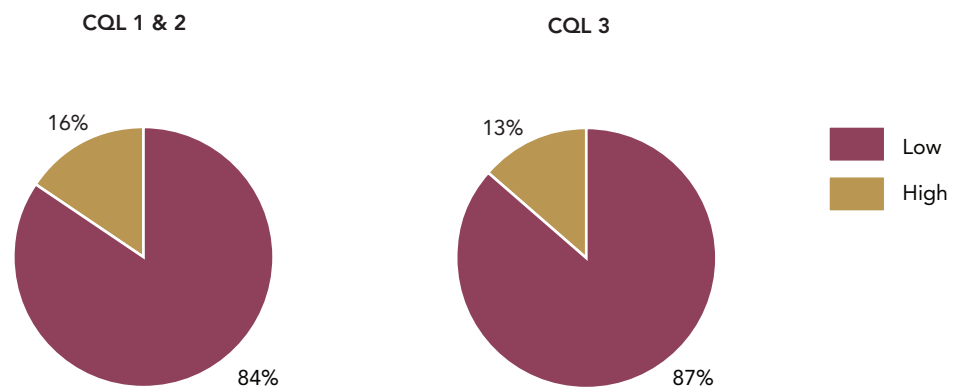16%   13%

84%   87%

Figure 19. The frequency of offset print demerits for CQL 1 & 2 companies vs. CQL 3 companies

Digital print demerits occur more frequently than offset print demerits. As seen in Figure 20, 78% of the companies with CQLs of 1 & 2 indicated that digital print demerits occur with low frequency, whereas 80% of CQL 3 companies indicated that digital print demerits occur with a low frequency. Again, both groups had similar rates of digital print demerits.

As seen in Figure 21, 89% of CQL 1 & 2 companies indicated that the severity of their offset print demerits was low. And 84% of CQL 3 companies indicated that the severity of their offset print demerits was also low. Again, the two groups were virtually the same in the severity of offset print demerits.
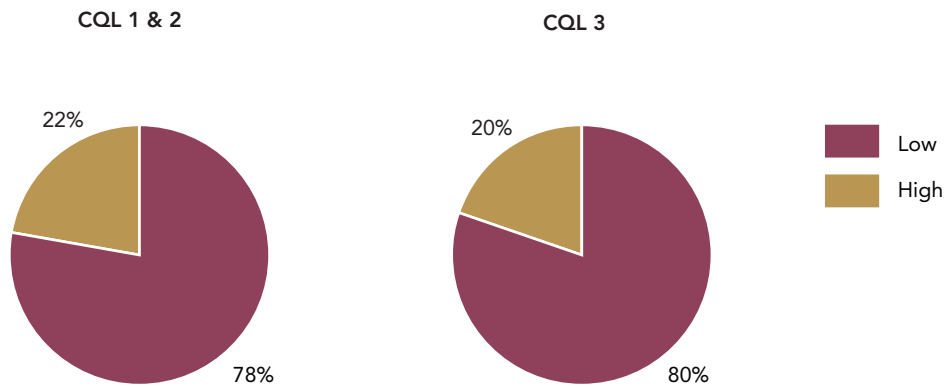
CQL 1 & 2 **CQL 3**

Figure 20. The frequency of digital print demerits for
CQL 1 & 2 companies vs. CQL 3 companies
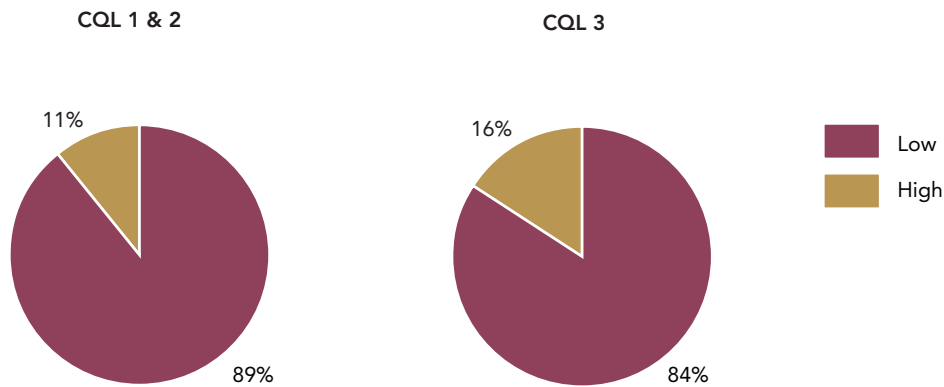
CQL 1 & 2 **CQL 3**

Figure 21. The severity of offset print demerits for
CQL 1 & 2 companies vs. CQL 3 companies

As seen in Figure 22, companies responded nearly identically to the severity of digital print demerits as they did to the frequency of digital print demerits, with 78% of CQL 1 & 2 companies indicating low severity of occurring digital print demerits, and 81% of CQL 3 companies indicating a low severity of occurring digital print demerits.

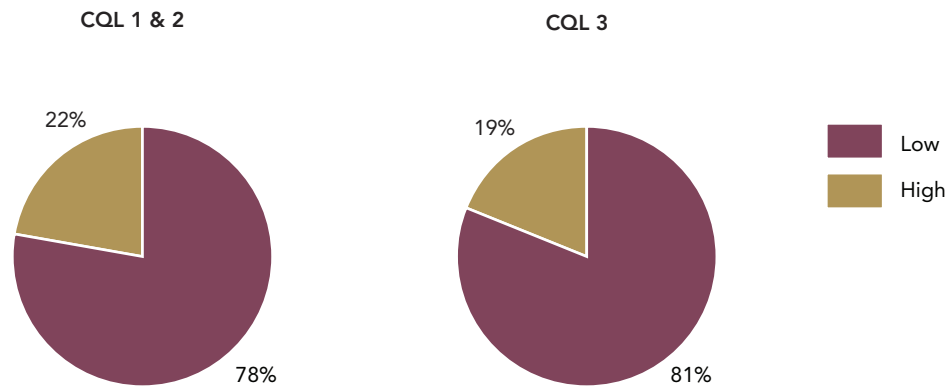CQL 1 & 2   CQL 3

Figure 22. The severity of digital print demerits for
CQL 1 & 2 companies vs. CQL 3 companies

When ranked, and as illustrated in Figure 23, the top three frequently occurring offset print demerits for CQL 1 & 2 companies were color variation, hickies, and color non-uniformity. This is compared to the top three frequently occurring offset print demerits for CQL 3 companies, which were hickies, color variation, and color non-uniformity.
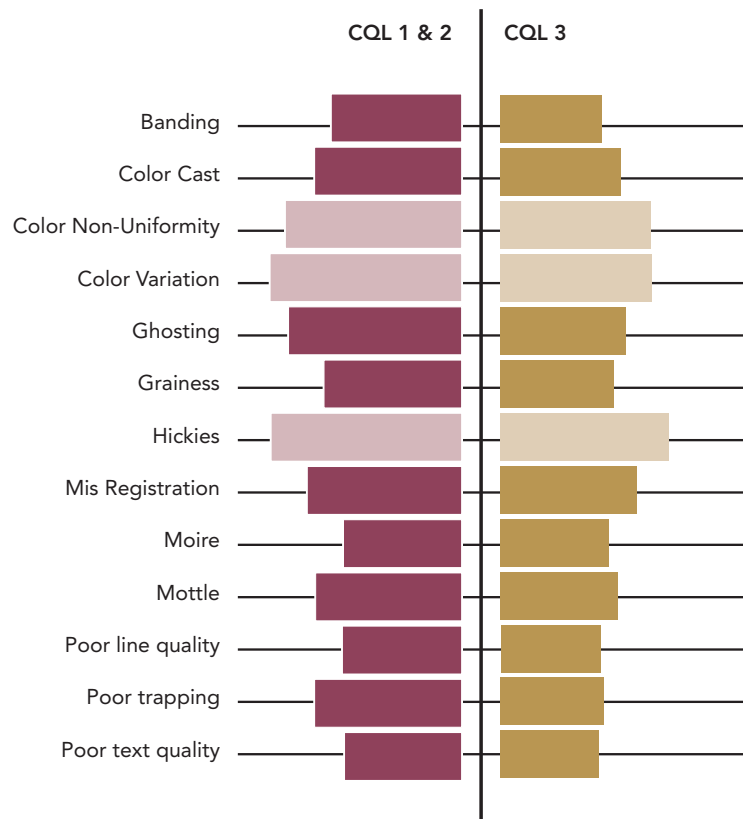

Figure 23. Offset print demerits by frequency for
CQL 1 & 2 companies vs. CQL 3 companies

As shown in Figure 24, the top three most frequently-occurring digital print demerits for CQL 1 & 2 companies were color variation, color non-uniformity and banding. Companies with CQL 3 experienced the same frequently-occurring digital print demerits as CQL 1 & 2 companies.
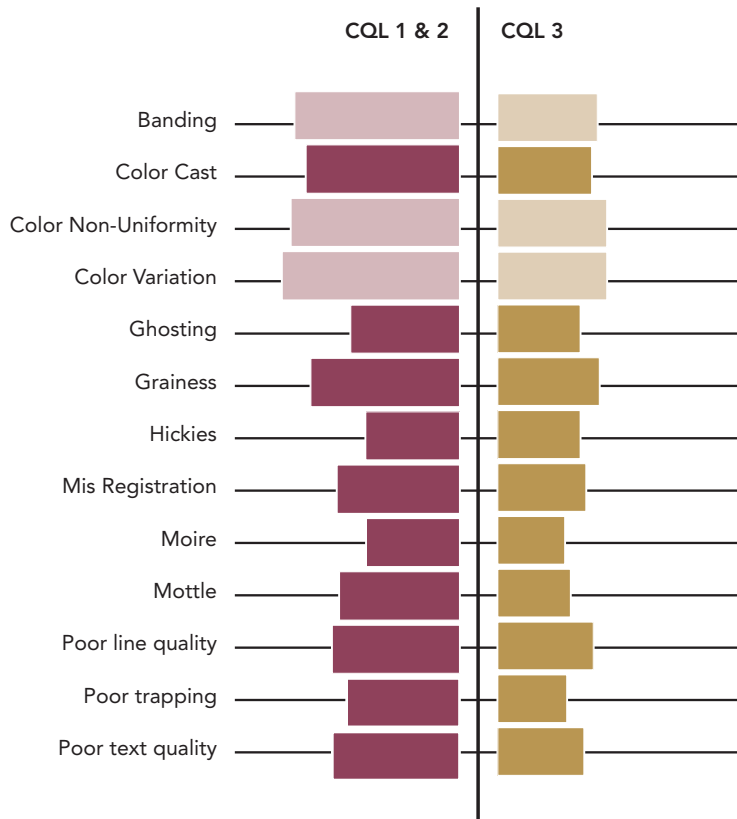

Figure 24. Digital print demerits by frequency for
CQL 1 & 2 companies vs. CQL 3 companies

Illustrated by Figure 25, the top three most severe offset print demerits in CQL 1 & 2 companies were color variation, color non-uniformity, and ghosting. The most severe offset print demerits in CQL 3 companies were color variation, color non-uniformity, and hickies.

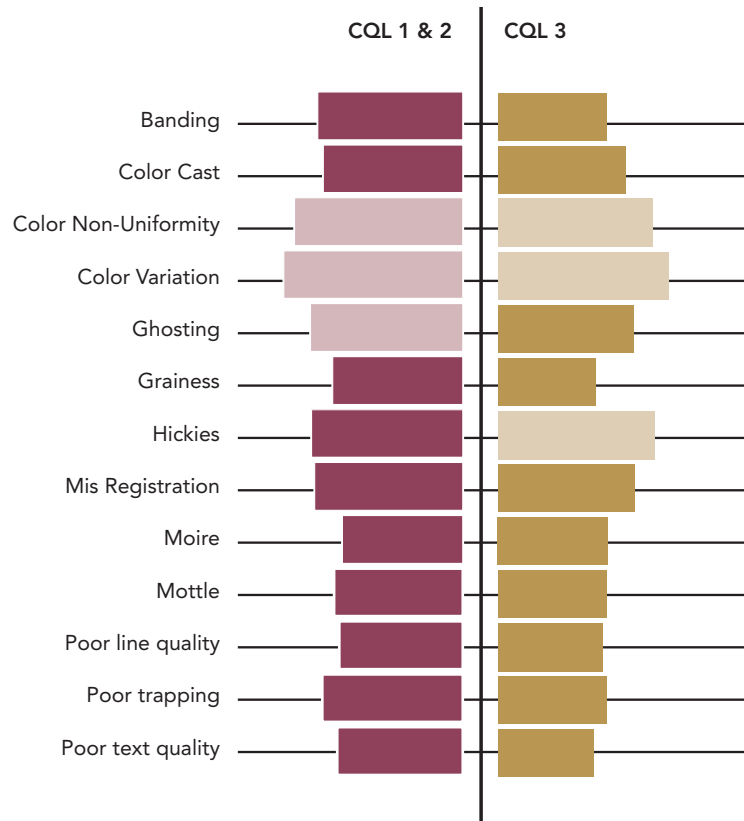|	CQL 1 & 2	CQL 3
Banding		
Color Cast		
Color Non-Uniformity		
Color Variation		
Ghosting		
Grainess		
Hickies		
Mis Registration		
Moire		
Mottle		
Poor line quality		
Poor trapping		
Poor text quality		

Figure 25. Offset print demerits of CQL 1 & 2 companies vs. CQL 3 companies by severity

As shown in Figure 26, the top three most severe digital print demerits for CQL 1&2 companies were nearly identical to the digital print demerits found most frequently, namely, banding, color variation and color non-uniformity. The top three most severe digital print demerits for CQL 3 companies were color non-uniformity, color variation, and color cast.
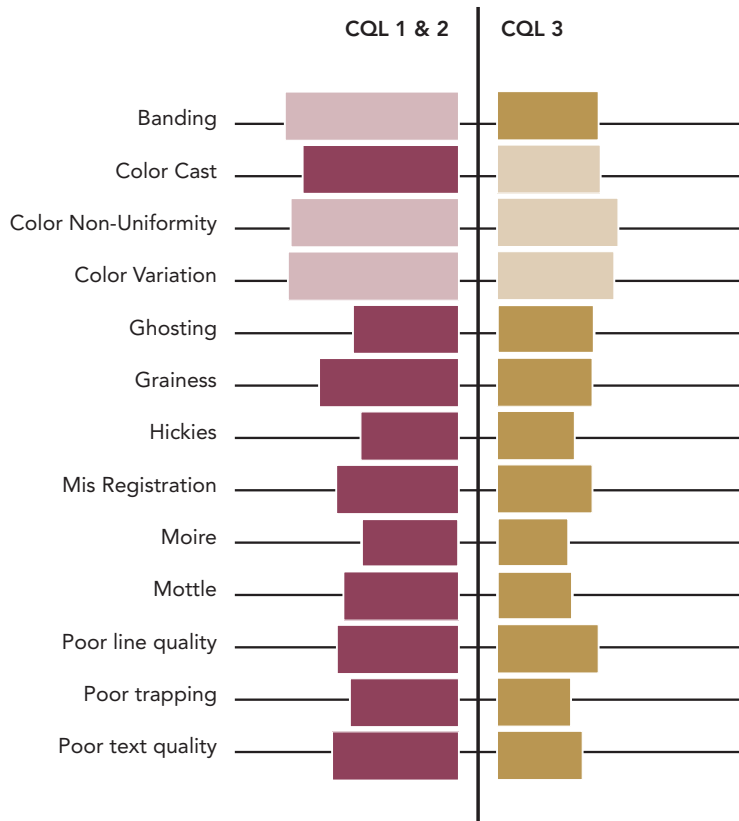
Figure 26. Digital print demerits of CQL 1 & 2 companies vs. CQL 3 companies by severity