print review
Volume 5: Summer 2008
For Affiliates of the Printing Industry Center at RIT

A Survey of Digital and Offset Print Quality Issues

Within the printing industry, quality is an important concept. However, quality assurance programs are not always in place to monitor print output when problems occur. Furthermore, with the myriad of printing technologies available for use today, problems may differ from process to process. These problems are investigated in the RIT Printing Industry Center's research monograph *A Survey of Digital and Offset Print Quality Issues*, by Robert Chung and Matthew Rees (PICRM-2006-04).

This project was prompted by input from the United States Government Printing Office (GPO) when it first became an industry partner of the Printing Industry Center 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.

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

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R·I·T Printing Industry Center

New RIT Publication Focuses on U.S. Printing Employment

A newly released publication from the Printing Industry Center at RIT analyzes core occupational employment within the U.S. printing industry. Titled *Printing Occupational Employment, High Wage Jobs & Industry Sources of Growth – 2001 to 2005*, the publication is authored by Dr. Maryellen Kelley, President of Pamet Hill Associates, a consulting group that specializes in economic analyses of innovation and government policy, including assessments of the impacts of technological change on industry and occupations.

The publication synthesizes the data collected by the U.S. Bureau of Labor Statistics' Occupational Employment Statistics (OES) program in their nationwide surveys and surveys of government agencies. Core printing-related occupations, industries of employment, occupational earnings, and employment growth are all analyzed during the survey period of 2001 to 2005.

Key findings include:

- **Expanding role of graphic designers:** Between 2001 and 2005, the overall demand for graphic designers from industry groups increased by 31.6%. Traditional print-producing groups contributed 27.1% of this growth, while industries relatively new to printing contributed 56.6% of this growth.
- **Industry shifts in employment of production printers:** The loss of production printer jobs nationally can be largely explained by the contraction of print production activity in two industry groups: Apparel/Textiles and Packaging. (Some of these losses may also reflect productivity improvements in print technology.) However, losses in one type of production job were often accompanied by simultaneous increases in the other type of job.
- **Employment growth in high-wage industries:** For desktop publishers, graphic designers, and press operators, at least half of all new hires occurred in industry groups with more high-wage than low-wage workers in these occupations.

The report is available as a softcover book (US $39.95) from Lulu.com.

Dr. Kelley is also a co-author of *Printing as an Industry, Commodity, and Activity: An Economic Analysis of Growth and Inter-Industry Transactions* with Nicholas Rockler. This report was released by the Printing Industry Center in 2006, and is also available as a softcover book (US $100.00) from Lulu.com.

More information is available at:
http://print.rit.edu/kelley

Paul & Louise Miller Lecture Series

The Paul & Louise Miller endowed professorship and the RIT School of Print Media have teamed up to sponsor a new lecture series. The inaugural lecture took place on April 30, 2008, and featured Michael G. Kane, president and publisher of the Rochester, NY *Democrat and Chronicle*.

Photo credit: A. Sue Weisler

Kane's presentation on the transformation of the news media sought to debunk several myths on the news industry while featuring the rapid changes that have taken place at the *D&C* under his leadership. The lecture was well attended by RIT students, faculty, and staff. Students also had the opportunity to participate in a networking and informational session following the lecture as part of the School of Print Media's sixth annual Industry Day.

RIT TAGA Chapter Receives Awards

Ten students from the RIT Technical Association of the Graphic Arts (TAGA) student chapter attended and competed at the 60th annual TAGA Technical Conference held in San Francisco, California from March 16-19, 2008.

Overall, the RIT technical publication received the most accolades from the judges of the competition with a total of three. The publication received the excellence in publication design award, the coveted attendee's choice award, and the Dusty Rhodes Graduate Paper award.

The Dusty Rhodes Graduate Paper award was received by recent RIT graduate student Kathryn O. Cole for her paper titled "Printability and Environmental Testing Using Silver-based Conductive Flexographic Ink Printed on a Polyamide Substrate."

RIT chapter Vice-President Cristina Stoll also exhibited her innovative work titled "Analysis of Spatial Uniformity and Temporal Consistency for the Heidelberg Anicolor Inking System"

Photo of RIT TAGA publication (Courtesy RIT TAGA)

during the student poster sessions. RIT student Brian Gamm served as a co-author of the work, which was advised by adjunct professor Franz Sigg.

Over the span of the conference, RIT chapter members networked with industry professionals and other students with a passion for the graphic arts. They also attended technical focus sessions, tutorials, and keynote addresses about emerging technologies.

Permanence of Toner on Paper—Based on the Life Cycle of Documents

As printing technology advances, new markets and applications are developing, requiring improved document longevity and robustness. With more documents being printed digitally, it is important to understand how these documents fare in terms of permanence in various stages of their life cycle, and how they compare to conventionally printed offset documents.

This concern is addressed in the RIT Printing Industry Center's research monograph *Permanence of Toner on Paper—Based on the Life Cycle of Documents*, by Franziska Frey, Ph.D., Henrik Holm Christensen, and Nicholas DiSantis (PICRM-2006-05). This research aims to understand the life expectancy of four categories of products printed with digital processes.

These four categories are:

- Marketing and promotional materials,
- Transactional and business communications,
- Direct mail, and
- On-demand color books.

Life Cycle Terminology

Life cycle theory is a framework for describing a system in constant change. Change is described as the development that these systems undergo throughout the stages of their life cycle. A stage is therefore made up of a specific set of processes that impact the system during its development.

With this in mind, this study has been constrained to the section of the digitally printed document's life cycle between the printing process and recycling. The stages included are:

- Printing and finishing,
- Mailing and fulfillment (mail preparation and fulfillment processes not including the actual physical distribution),
- Distribution (this includes all steps of the physical distribution),
- Usage, and
- Recycling.

In these five life cycle stages, physical and chemical stress is inflicted on the print. Since four categories of digital printed documents are dealt with, the processes within the stages of each category might differ slightly.

Factors of Stress Induction

The determining factor in the choice of digital printing technology for producing the four document categories of this study is highly dependent upon costs

Table 1. The main types of stressors that confront the four document categories

Stress	Type	Test	Testing Instrument
Scratching	Physical	Abrasion resistance Rub resistance	Taber Abrasion Tester Sutherland Rub Test
Cracking	Physical	Folding test	Fold tester
Solvent	Chemical	Solvent resistance test	
Light (UV)	Chemical	Lightfastness	Fluorescent / Xenon Light Chamber
Moisture	Chemical	Humidity-fastness Water resistance DIN-16524-1	
Heat	Chemical	Thermostability	
Air contaminants	Chemical	Gas-fastness, ozone test	Ozone Chamber

as well as life cycle requirements. Costs are determined from the product specification, complimentary services, and pricing strategy of the producer. With this quantity of variables it is impossible to determine the exact distribution of preferred digital printing technologies within the four document categories of this study, or to accurately predict future developments in technology and the marketplace. Therefore, inkjet, dry toner, and liquid toner printing technologies are regarded as having equal importance for producing the four document categories.

These three printing process technologies, the formulation of their colorants, and the characteristics of the substrates dedicated to them of course vary. The effect of the types of stress induced on them therefore varies as well. Inkjet is more vulnerable to certain types of stress than toner-based technologies. There is also a difference in the effects of stress between dry and liquid toner print, but due to the similarity of the technologies, the differences are smaller.

Each of the three digital processes (inkjet, dry toner and liquid toner) is dealt with individually throughout the stages of the life cycle in further analysis.

Processes in the Five Life Cycle Stages

Stage One – Printing and Finishing

Printing: Toner-based technologies. In these types of printing technologies, the most important step from the life cycle point of view is the adhering ("fixing" or "fusing") of toner to the surface of the paper. The adhesion of the toner to the paper surface, which happens during toner fixing, is both a mechanical and chemical adhesion. The mechanical adhesion involves polymeric toner molecules penetrating into the voids of the paper surface and interlocking with the solid surface and each other. Since the strength of the mechanical adhesion is dependent upon the degree of "intermingling," smaller polymer molecules are preferable. They tend to mingle better in the locations of the voids between fibers, and therefore create stronger bonds in these areas.

In chemical adhesion, the most applicable theory is absorption. This adhesion strength is determined primarily by the wetting of the paper from the toner's resin. The strength of chemical adhesion is thus highly dependent on the paper's surface energy properties for the chemical bonds to endure stress.

Printing: Inkjet printing technologies. The absorption of ink into the paper in inkjet printing is the major difference between toner-based and inkjet printing technologies. It is also the reason why abrasion resistance and adhesion strength are, in most cases, less critical issues to investigate when looking at inkjet print permanence. However, substrate properties like media pH, surface coating nature and location of the colorant have a big impact on aging properties of inkjet materials.

Finishing. The amount of stress applied to substrates in the various printing processes is minimal compared to the physical stress applied in all phases of finishing. Table 2 (shown on page 9) summarizes the stress types and categories that can occur in the printing and finishing stage.

Stage Two – Mailing (Mail Preparation) and Fulfillment

This stage of the life cycle was defined to include mail preparation and various fulfillment processes not including the actual physical distribution of the process. Mailing and fulfillment are usually

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Digital and Offset Print Quality Issues *continued*

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.

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. 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

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

is highly dependent on the substrate, whereas digital image quality is less dependent on the substrate. The study also exposed the two print attributes that 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.

Findings

Based on the survey, three distinct groups of respondents were created. Tier 1 consisted of all respondents, Tier 2 consisted of respondents who provide both offset and digital print services, and Tier 3 consisted of respondents who provide both offset and digital print services and whose customers have formal quality requirements. The comparative results between these three groups are detailed below.
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.

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 one 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. As seen from the data gathered, a large percentage of offset printers experiment to resolve frequent or severe 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 issues 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.

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Digital and Offset Print Quality Issues *continued*

Conclusions

The key findings of the survey can be summarized as such:

- 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.
- Less than 25% of the respondents using both digital and offset processes indicated that their customer quality requirements are documented. However, it was found that having formal procedures in place for expressing quality did not have an impact on the type of demerits occurring or on the frequency or severity of print demerits occurring.
- 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.
- The root causes of print demerits are:
  - » *The open-system nature of offset printing technology. That is, print demerits are often the result of incompatible consumables, such as paper grades.*
  - » *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.).*

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.

To read about this research in detail, download the monograph from:
print.rit.edu/pubs/picrm200604.pdf

Research Monographs of the Center

Expert faculty from the School of Print Media, the E. Philip Saunders College of Business, and other fields at RIT comprise the cadre of researchers that build and carry out the research initiatives undertaken by the Center. The research agenda is built through collaboration between Center researchers and Industry Partner companies, resulting in research that is cross-disciplinary and highly relevant to industry concerns.

Take advantage of this resource at:
print.rit.edu/research

Permanence of Toner on Paper *continued*

tied together because fulfillment can include mailing. Fulfillment is viewed as a value-added service which an increasing number of print services providers are offering. (See Table 3.)

Stage Three – Physical Distribution
Distribution normally takes place after finishing, and involves a printed product being sent directly to the customer, end user, a distributor, or a warehouse. For print services providers or third parties that offer distribution services, costs, handling procedures, storage, and safety are of the utmost concern.

Distribution is a key part of the digital print life cycle because, in most cases, it is the final stage before the end user.

A shift in distribution trends in the past few years has addressed some concerns of distributors. Historically, printers followed a "print and distribute" business model, that is, physically printing the product in one location and then delivering it to a remote end user. In the newer "distribute and print" business model, electronic files are distributed close to the ultimate product destination and then printed. This workflow reduces distribution stresses and is a breakthrough in cost efficiency as well as storage and safety.

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Table 2. Summary of processes in the printing and finishing stage and their contribution of stress to printed products

Process	Document Category	Stress Category	Stress Type
Printing	All	None	None
Folding	All	Physical	Cracking
Stitching	Marketing and promotional materials	Physical	Cracking
Wire comb binding	On-demand color books	Physical	Scratching, cracking
Tape binding	On-demand color books	Physical	Scratching
Perfect binding	On-demand color books	Physical	Scratching, cracking
Trimming	All	Physical	Scratching

Table 3. Summary of the processes in the mailing and fulfillment stage and their contribution of stress to printed products

Process	Document Category	Stress Category	Stress Type
Collecting	Direct mail Marketing & promotional materials Transactional & business communications	Physical	Scratching, cracking
Inserting	Direct mail Marketing & promotional materials Transactional & business communications	Physical	Scratching, cracking
Wrapping/ packing	All	Physical/chemical	Scratching, heat
Addressing	Direct mail Marketing & promotional materials Transactional & business communications	Physical/chemical	Scratching, light, heat
Pre-postage sorting	Direct mail Marketing & promotional materials Transactional & business communications	Physical/chemical	Scratching, cracking, heat
Postage application	Direct mail Marketing & promotional materials Transactional & business communications	Physical/chemical	Scratching, heat
Ware-housing/ storage	All	Physical/chemical	Scratching, air contaminants

Permanence of Toner on Paper *continued*

However, both models still do entail stresses on the printed product, including scratching, cracking, moisture, heat, and air contaminants. These stresses are outlined in Table 4.

Stage Four – Usage

Permanence issues, quality, and archivability are most critical at this stage. The definition of permanence depends on the type of product and its purpose. The principal documents focused on in this study include: marketing and promotional materials, direct mail, transactional and business communications, and on-demand color books. Based on the materials and processes used, these products vary widely in terms of user expectations about permanence.

Table 5 summarizes the processes in the usage stage and their contribution of stress to the prints.

Stage Five – Recycling

Recycling digitally printed materials is more complex than recycling offset lithographic materials. Traditionally, the recycling process began with a process to de-ink the printed sheets. To improve ink release, chemicals such as caustic soda, sodium silicate, hydrogen peroxide, and soap were introduced during the repulping stage of paper, making a slurry of paper fibers. However, most digitally printed products are very difficult to process this way, due to the synthetic binders used in toners. During the first stage of the process, the toner tends to break up into very large particles, some of which are too large to be removed, unlike conventional printing ink particles.

For the recycling process to be economical as well as able to produce quality recycled papers, toners must be almost completely removed from the pulp. With digital printing taking more of the market share from traditional offset lithography, this could pose a serious problem in the future. However, testing has indicated that recycled paper produced from digital printing is comparable to recycled paper produced from offset printing. New methods of efficiently recycling digitally printed products need to be explored.

Life Cycle Overview

The four document categories in this study encounter similar problems in their life cycle stages. Their situations differ, however, in the printing and finishing stage and in the mailing and

Table 4. Summary of the processes in the distribution stage and their contribution of stress to printed products

Process	Document Category	Stress Category	Stress Type
Sorting	All	Physical/Chemical	Scratching, cracking, heat
Packing	All	Physical	Scratching, heat
Transportation	All	Physical/Chemical	Scratching, moisture, heat
Delivery	All	Physical/Chemical	Scratching, cracking, moisture, heat

Table 5. Summary of the processes in the usage stage and their contribution of stress to printed products

Process	Document Category	Stress Category	Stress Type
Usage	Marketing & promotional	Physical/chemical	Scratching, cracking, moisture, heat
	Direct mail	Physical/chemical	Scratching, cracking, moisture, heat
	Transactional/Business communications	Physical/chemical	All but solvents
	On-demand color books	Physical/chemical	All

fulfillment stage. Figures 1 through 4 depict the processes in the life cycle stages of each category. Note that the mailing and fulfillment stage includes mail preparation and fulfillment tasks not including the actual physical distribution. The distribution phase includes the physical distribution steps.

Conclusion

Digital printing has been projected to be the fastest growing print provider service over the next two years, and therefore understanding the variables that cause stress to the process is valuable. Stressors that potentially affect permanence were examined in each stage of digital printing's life cycle:

- In the printing and finishing stage, little stress is induced by the actual printing, but physical scratching and cracking occur during finishing. During the mailing and fulfillment stages, scratching and cracking, and heat, light, and air contaminants were seen as stressors.
- Similarly, scratching, cracking, heat and moisture were identified as problems in the distribution stage.
- In the usage stage, printed materials are subjected to every type of stress found in Table 1 such as: scratching, cracking, solvents, light, humidity, heat and air contaminants.

Figure 1. The processes in the life cycle of marketing and promotional materials

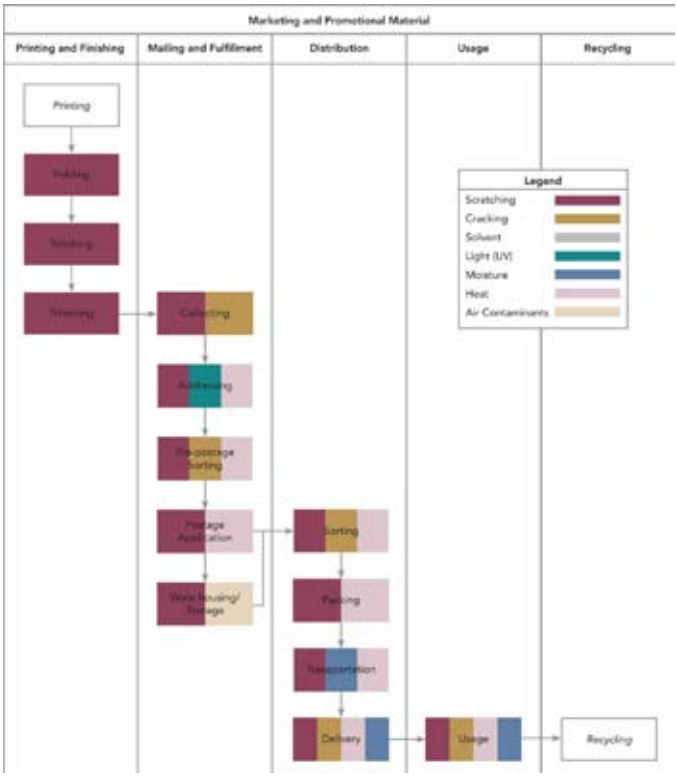


Figure 2. The processes in the life cycle of direct mail

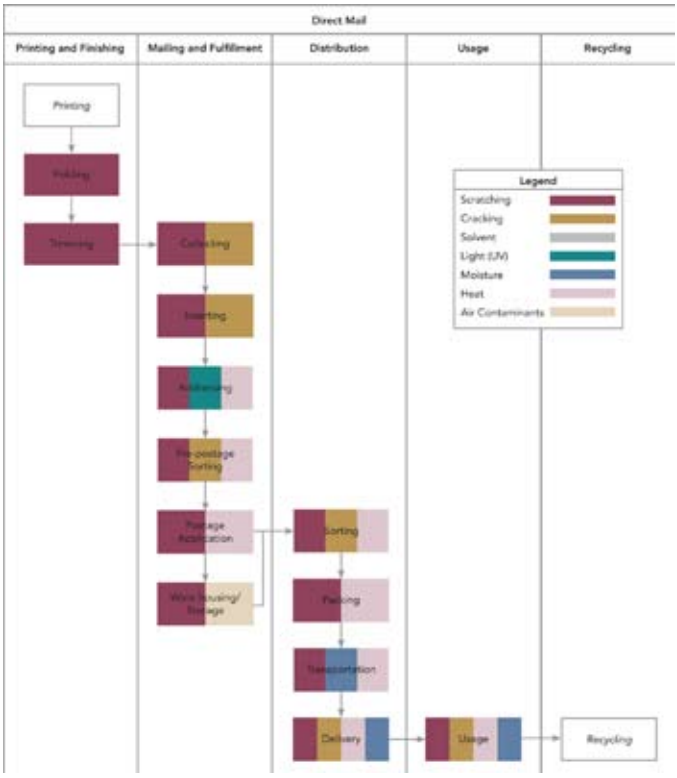


Figure 3. The processes in the life cycle of transactional and business communications

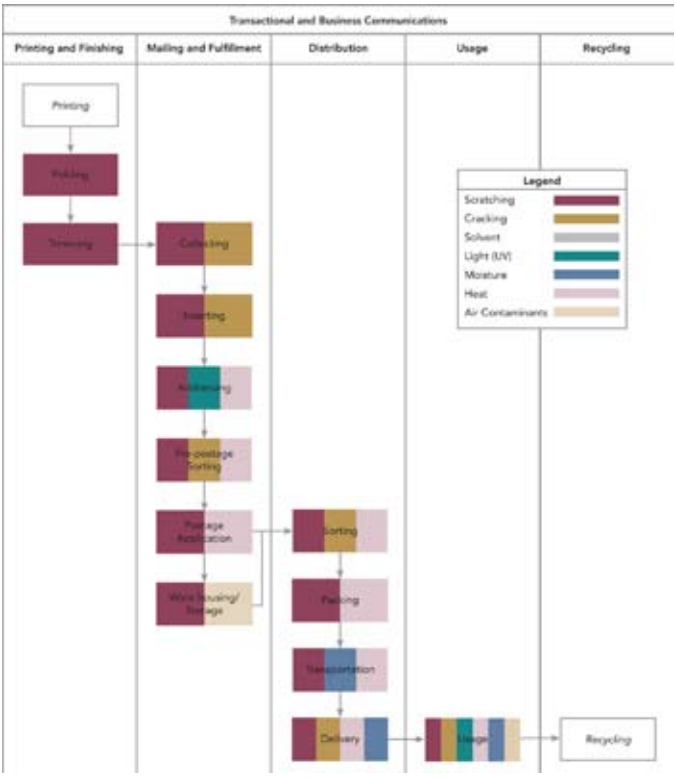
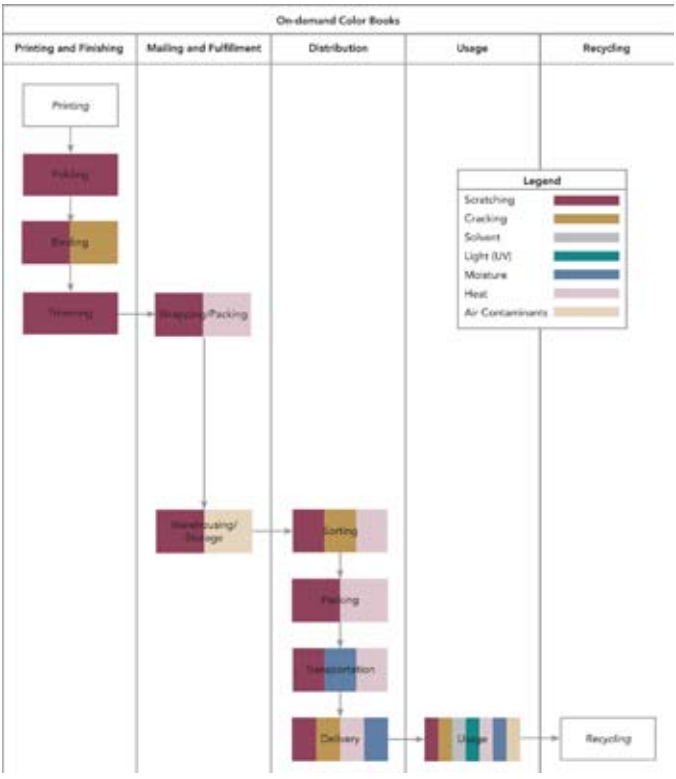


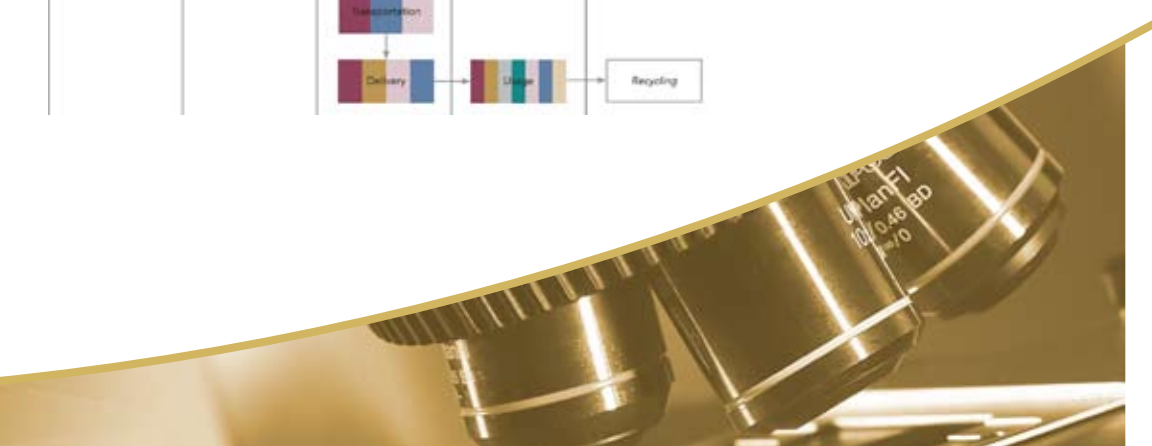
Figure 4. The processes in the life cycle of on-demand color books



• Lastly, recycling digitally printed products presents obstacles not encountered in the processes used for offset printed materials.

With one-to-one marketing, variable data, and print-on-demand becoming so popular, research in this area is necessary for every player in the printing industry to understand.

To read about this research in detail, download the monograph from: print.rit.edu/pubs/picrm200605.pdf



About the Center

Rochester Institute of Technology (RIT) was selected by the Alfred P. Sloan Foundation in 2001 to join the family of Sloan Industry Centers located at prestigious universities across the U.S. The Printing Industry Center at RIT is a joint program of the School of Print Media and RIT's College of Business, emphasizing Sloan's long-standing tradition of applying a broad multidisciplinary approach to industry investigations and findings.

Dedicated to the study of major business environment influences in the printing industry brought on by new technologies and societal changes, the Printing Industry Center at RIT addresses the concerns of the printing industry through educational outreach, research initiatives, and print evaluation services. The Center creates a forum for printing companies and associations worldwide to access a neutral platform for the dissemination of knowledge that can be trusted by the industry, to share ideas, and to build the partnerships needed to sustain growth and profitability in a rapidly changing market.

With the support of RIT, the Alfred P. Sloan Foundation, and our Industry Partners, it is our mission to continue to develop and articulate the knowledge necessary for the long-term economic health of the printing industry.

More information on the Printing Industry Center at RIT and its research activities can be found online at http://print.rit.edu.

Industry Partners

Support for the Printing Industry Center at RIT comes from:

print review
Volume 5: Summer 2008

About the PrintReview

The Print Review is produced quarterly exclusively for Affiliates of the Printing Industry Center at RIT. Membership and PrintReview subscription is free upon request. To register, go to: http://print.rit.edu/affiliates/ or call 585-475-4231.

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