Toward Better Image Reproduction in Offset

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Doctoral Thesis

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## Contents

Preface ............................................................................................................. 5  
Abstract ........................................................................................................... 7  
Keywords ........................................................................................................ 8  
Acknowledgements ........................................................................................... 9  

1. Introduction ............................................................................................. 11  
   1.1 Color rendering ............................................................................... 12  
   1.2 Color Management System ............................................................ 14  

2. The objectives of this work ..................................................................... 18  
   2.1 Delimitation .................................................................................... 20  

3. Methodology ............................................................................................ 21  

4. Theoretical considerations ..................................................................... 23  
   4.1 The need for image classification ................................................... 23  
   4.2 The need for a common terminology ............................................. 24  
   4.3 Images and image categories .......................................................... 24  
   4.4 Tonal range and tone compression of images ................................. 30  
   4.5 Situation today - digital cameras .................................................... 32  
   4.6 The standardization of the printing process .................................... 35  

5. Summary of original work ..................................................................... 51  
   5.1 Paper I ............................................................................................. 53  
   5.2 Paper II ........................................................................................... 65  
   5.3 Paper III .......................................................................................... 69  
   5.4 Paper IV .......................................................................................... 73  
   5.5 Paper V ........................................................................................... 77  
   5.6 Paper VI .......................................................................................... 83  
   5.7 Paper VII ......................................................................................... 87  
   5.8 Paper VIII ....................................................................................... 91  

6. Conclusions and discussion .................................................................. 99  
   6.1. The first objective .......................................................................... 99  
   6.2. The second objective .................................................................... 100  
   6.3. The third objective ....................................................................... 103  
   6.4 Standardization as an adaptation .................................................. 105  

7. Concluding remarks .............................................................................. 106  

8. The author’s contribution to the papers .......................................... 107  

Appendix ...................................................................................................... 111  
References .................................................................................................. 123  
Original Papers .......................................................................................... 133
Preface

This thesis is based on the eight papers, listed below, which are referred to in the text by their Roman numerals.

**Paper I** - Enoksson Emmi

“*Image Classification and Optimized Image Reproduction*”

TAGA 2003, Montreal, Canada, Taga Proceedings 2003, pp 33-36

**Paper II** - Enoksson Emmi, Aviander Per

“The characterization of input devices by luminance and chrominance”

VI. Polygraficky seminar, 2003, Pardubice, Czech Republic, 10 pages

**Paper III** - Enoksson Emmi

“*Image Reproduction Practices*”


**Paper IV** - Enoksson Emmi

“*Digital Test Form for ICC-profiles*”


**Paper V** - Enoksson Emmi, Aviander Per

“*Demand specifications for controlled color reproduction*”

VII. Polygraficky seminar, 2005, Pardubice, Czech Republic, 11 pages

**Paper VI** - Enoksson Emmi, Bjurstedt Anders

“*Compensation by black - a new separation?*”


**Paper VII** - Norstedt Sofia, Kolseth Petter, Enoksson Emmi

“*Using Gray-Balance Control in Press Calibration for Robust ICC Color Management in Sheet-Fed Offset*”


**Paper VIII** - Enoksson Emmi, Ullberg Jonas

“*Gray Balance Control in Sheet-Fed Offset Printing*”

Abstract
This thesis has focused on color reproduction processes in the graphics field and is based on theoretical research and practical studies. The purpose of this thesis was to investigate how new tools and tools adapted to a specific production set-up can be used to raise awareness regarding the quality and workflow of images and image processing for sheet-fed offset within the graphic industry.

The work is divided into the following three study areas with several sub-studies:

1) The first research goal of the thesis is to identify knowledge levels regarding color separation of images and demand specifications within printing houses.
2) The second research goal is to investigate whether novel tools and new terminology can help to increase the knowledge level regarding color management.
3) The third goal is to investigate whether process specific adaptation of key color control tools can improve quality levels.

Three surveys about color reproduction (focusing on level of knowledge concerning color separation, the use of ICC-profiles and demand specifications for controlled color reproduction) at printing companies in Sweden were made between 2000 and 2004. The surveys indicated a serious problem in the graphic arts industry, involving both an insufficient understanding of color management and a lack of communication.

An important part of the work was to assist in make color management understandable for users and thereby optimize printing. For this purpose, digital test forms have been developed. The developed tools, together with descriptive material, will facilitate the understanding of color management issues. Definitions within the field of color separations have been examined, and changes have been suggested. A new term for separation “Compensation by Black”, CB, has been suggested, instead of e.g. GCR and UCR.

Is it possible to adapt the different parts of the process chain in order to achieve an improved production? Yes! This work has developed the method for adaptation of the scanner test chart, the printing test chart for image categorization and the control strip for sheet-fed offset using gray balance. This thesis suggests that it is possible to produce a custom-made IT8 target test chart for scanners and achieve a result at least similar to or even better than the standard test charts on the market. This work has also shown that it is possible to adapt the test chart for printing to image category. The result showed that low-key image separated by the image-adapted test chart showed more detail in the dark areas than a low-key image separated by the standard test chart, in the prints on a coated paper. The result from the adaptation of a control strip for sheet-fed offset showed that gray balance can be used as a control parameter for quality control in sheet-fed offset.
Keywords

Images, offset, printing, ICC, color, gamut, profile, calibration, separation, GCR, UCR, characterization, gray balance.
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1 Introduction

The production of a printed product involves three stages: prepress, the printing process (press) itself, and finishing (postpress), see Figure 1. These separate production stages are connected by a flow of materials, such as printing plates between prepress and press and printed sheets between press and postpress. The interconnection between the production stages has become increasingly marked by the data flow. Information is exchanged both for the actual production of special printed products and for the organization of the business and production cycles. Information and data are essential requirements for the optimal and reliable functioning of individual production processes and equipment, and for an efficient, high-quality and economic production. (Kipphan, 2001)

This thesis focuses on image reproduction as it is a part of the prepress process. Prepress includes all the steps which are carried out before the actual printing, where information is transferred onto paper or another substrate.

Today, text, images and layout can be prepared either by customers, the author, or an agency. This division of work is also applicable to the jobs carried out within a printshop where a prepress stage included. The basic stages in the creation of a digital page are shown in Figure 2.
1.1 Color rendering

It is important to achieve the best possible reproduction of an image in printing. High quality is crucial for both print customers and the final users. There are various types of equipment (i.e. printing machinery) and many applications (i.e. image processing, profile making) on the market. Each type of equipment and each application has its own characteristics and algorithms and works in its own way. The variety of, for example, proof printers and digital test printing equipment of varying quality has also increased dramatically during the last decades. Not only do these types of equipment work in different ways, but they also render colors in different ways, and this generates certain practical problems for the workflow. If one scans an image using two different scanners, one will usually obtain two different results. If one prints using two different printers or printing machines, one will also obtain different results.
first problem/phenomenon is related to the device-dependent additive color system* and the second to the device-dependent subtractive color system*. The terms additive and subtractive are used to differentiate between the mixing of colored lights, and the mixing of colorants (Billmeyer, Saltzman, 1981). The fact that two devices are based on the same color system does not necessarily mean that they will render color in the same way. Different monitors (even of the same model and from same company) which are RGB*-based (Red, Green, Blue) often render colors in different ways. In general one could say that all hardware on the market has their own fingerprint in their way to render colors.

Therefore, all equipment must be under strict control, i.e. correctly adjusted and calibrated* in order to show colors correctly. Generally seen, all equipment has a lifetime during which they also wear from their use, and therefore also maintenance in the form of calibration is needed to assure all color is rendered accurately.

To achieve a print result with predictable color is thus complicated. A great help is “color management which attempts to make color more predictable within the limitations of the devices in use” (Adams, Weisberg, 2000). Color management translates color between devices using a device-independent profile connection space (PCS, see 1.2.1.3) and standard profiles for each device. A profile characterizes a device’s color reproduction capabilities (Adams, Weisberg, 2000). The color units (for example scanner, display, printer) are characterized in a common general format, ICC (International Color Consortium*). Through the ICC-format, ICC-profile*, various colors and hues can be interpreted in a similar fashion regardless of the platform and application (computer type, monitor model, system construction and pre-press programs), illustrated in Figures 3 and 4. The ICC-format enables the color space* of a color unit to be determined from a large number of measured values, and thus enables, for example, optimization of printing simulations, by using color engines or color profiling. Before the ICC-format was introduced, color separation* was performed directly in image scanners or in imaging applications (i.e. Adobe Photoshop), where the color was mainly visually evaluated individually for various types of output devices, i.e. printing machinery.
1.2 Color Management System

A color management system (CMS) is a collection of color management software tools used to try to make the color to be reproduced device-independent. Ideally, the colors on your monitor should accurately represent both the colors in a scanned image and the colors you will see on the final output. A CMS maps the colors in the color gamut* of one device into a device-independent color space, and then transforms those colors to the color gamut of another device. (Adobe 2006)
Color management operations can be described in terms of the four “Cs”: consistency, calibration, characterization and conversion. The four ”Cs” provide a handy framework for organizing the steps which must be done to obtain accurate, consistent color in profiling devices. Color management is not just profiling (the third ”C, characterization). It also involves calibration of devices prior to profiling (the second ”C”); and optimization, if necessary, of settings prior to calibration (the first ”C”, consistency). After these three steps have been accomplished, color workflow programs can use the ICC profile to convert (the fourth ”C”) color accurate, color-matched output. (Adams II, Sharma, Suffoletto, 2008)

1.2.1 ICC - International Color Consortium

The ICC was formed in 1993 to seek to establish specifications and guidelines for the manufacturers and developers of software, equipment, and producers in terms of color management systems (Field, 2004). The main document produced by the ICC is ”The ICC Profile Format” specification, which describes an open profile format which all vendors can use. By defining a format which allowed consumers to mix and match profiles created by different vendors, the ICC standardized the concept of profile-based color management (Fraser, Murphy, Bunting, 2003).

The ICC has done an important job within standardization, to promote the use and adoption of open, vendor-neutral, cross-platform color management systems. The ICC is actively working to make the ICC specification more useful to the various constituencies which have adopted ICC workflows. The ICC encourages vendors to support the ICC profile format and the workflows required to use ICC profiles.

1.2.1.1 ICC-profiles

An ICC-profile is a file of data describing the color characteristics of a device such as a scanner, monitor, or printer. The primary purpose of this file is for use in color management software to maintain color consistency in imagery viewed, displayed or printed on various devices. The file contains descriptions of specific devices and their settings, together with numerical data describing how to transform the color values which are to be displayed or printed on the used device. The numerical data includes matrices and tables which a color management module (CMM) uses to convert that device’s color data to a common color space, defined by the ICC and called the profile connection space (PCS), and back to the device’s color space. (Wallner, 2000)
1.2.1.2 CMM
The Color Management Module is the software “engine” which does the job of converting the RGB or CMYK* values using the color data in the profiles. A profile cannot contain the PCS definition (see 1.2.1.3) for every possible combination of RGB or CMYK numbers so the CMM has to calculate the intermediate values. The CMM provides a method which the color management system can use to convert values from source color space to the PCS and from the PCS to any destination space. (Fraser, Murphy, Bunting, 2003). It may depend on the CMM software used and its algorithms how accurately the CMM actually works.

1.2.1.3 PCS - Profile Connection Space
Color management uses an ICC profile to translate the image data to PCS, see Figure 5. A profile contains two sets of values, RGB or CMYK device control values, and the corresponding CIE XYZ* or CIE LAB* (Fraser, Murphy, Bunting, 2003). The standard color space is the interface which provides an unambiguous connection between the input and output profiles, as illustrated in Figure 4. It allows the profile transforms for input, display, and output devices to be decoupled so that they can be produced independently. A well-defined PCS provides a common interface for the individual device profiles. It is the virtual destination for input transforms and the virtual source for output transforms. If the input and output transforms are based on the same PCS definition, even though they are created independently, they can be paired arbitrarily at run time by the color-management engine (CMM) and will yield consistent and predictable results when applied to color values (ICC, 2006).

![Image of color space diagram](image)

**Figure 5:** A profile contains two sets of values, RGB or CMYK device control values, and the corresponding CIE XYZ or CIE LAB values that they produce. (Fraser, Murphy, Bunting, 2003). The values are converted from source color space to the PCS and from the PCS to any destination space.
The profile connection space makes it possible to give a color an unambiguous numerical value in CIE XYZ or CIE LAB which does not depend on the quirks of the various devices used to reproduce that color, but instead defines the color which is actually seen (Fraser, Murphy, Bunting, 2003).

Converting colors always requires two profiles, a source and a destination. The source profile tells the CMS (Color Management System) which colors the document contains, and the destination profile tells the CMS which new set of control signals is required to reproduce these colors on the destination device.

1.2.2 Color Management (CM)
Based on a survey (Marin, 2004), the following points should be kept in mind to be successful when implementing color management:

• *implement process controls in your organization*
  Process controls are the key factors for successful CM. A process which is not consistent and repeatable will render a color profile useless.

• *the CM process requires training*

• *know that color management is a process*
  Color management is not just a software application, a measuring device, and a profile.

• *give it time*

Performing color management requires knowledge and expertise. One important source of knowledge and expertise is external consultants. Technological development in the graphics industry proceeds very fast, and consultants tend to specialize in different parts of the printing process to meet the needs. Consultants are commonly hired in the graphic industry, often possessing important knowledge that they disseminate at the printing houses. However, the consultants’ knowledge is often not adapted to a specific company’s production step. It is important that the printing houses use the consultants appropriately, making appropriate demands in order to meet the needs.
Objectives

2 The objectives of this work

The purpose of this thesis is to investigate how new tools and tools adapted to a specific production set-up can be used to raise awareness regarding the quality and workflow of images and image processing for sheet-fed offset within the graphics industry. Much emphasis has been put on the development of novel, adapted tools which are pedagogically structured so that an operator’s understanding is considerably facilitated. The focus of this thesis lies on the pre-press and printing processes see the red solid circles in Figure 6. Although the focus lies on these steps in the production flow, the whole production flow is affected (see broken red circles), as the different steps interact. A workflow consists of a sequence of connected steps. In a functioning workflow, any given step has to be adequately developed and optimized, in order for subsequent steps to function satisfactory, thus generating a continuous workflow. This can be exemplified by an image that is to be adapted for printing. The image must be separated using the correct ICC-profile already at the pre-press step in order to reproduce colors in the best possible way during the actual printing step.

![Figure 6: Production flow, material and data flow for print media production (Kipphan, 2001).](image)

The work is divided into the following three study areas with several sub-studies:

1. The first research goal of the thesis is to identify knowledge levels regarding color separation of images and demand specifications within printing houses:

   1.1 Color separation of images
   - the purpose has been to investigate the actual knowledge level regarding color separation, ICC-profiles and color management in various printing houses in order to find new ways of improving the knowledge.
1.2 Demand specifications for controlled color reproduction
- the purpose of this study was to define specifications to simplify and improve color communication concerning color separation not only between consultants and printers but also internally between the prepress and pressroom departments within the various companies.

2. The second research goal of this thesis is to investigate whether novel tools and new terminology can help to increase the knowledge level regarding color management:

2.1 Pedagogical tools for color management and ICC-profiles
Can novel tools, with emphasis on pedagogy, be used to improve understanding of color management?

2.2 Suggestions for an improved terminology concerning color separation
Is it possible to simplify the color separation terminology in order to facilitate this understanding?

3. The third goal is to investigate whether process specific adaptation of key color control tools can improve quality levels:

3.1 Adaptation of a scanner test chart
Is it possible to produce a custom-made IT8 scanner test chart for each scanner and achieve a better/similar result than with the standard test charts on the market? Is there any advantage in producing your own test chart?

3.2 Adaptation of a printing test chart to the image category
The hypothesis is that it is possible to adapt the test chart to an image category, and thus give priority to sections of the tonal range.

3.3 Adaptation of a control strip for sheet-fed offset
Newspaper printing in Sweden is often controlled using visual gray balance assessment. Is it possible to adapt this gray balance control of printing to sheet-fed offset printing?
2.1 Delimitations

The thesis focuses on the lithographic offset process, especially sheet-fed offset, and the pre-press and printing processes. Test printing for adaptation of the test chart for images was carried out using a laboratory offset press, Heidelberg Speedmaster-74. The printing with gray balance was carried out at the printing house using the Heidelberg Speedmaster-74 (using Spektra screening, a hybrid half-tone screening technology).

Much of the work on images and test charts has been carried out using commercially available software, the inner workings of which are not published in detail. However, since these are examples of software in common use in image processing and color reproduction, the studies and results are valid and important from a practical and pedagogical perspective.

Aspects of image quality not covered in this thesis include for example paper characteristics, ink properties and rip settings.
3 Methodology

This work is based on theoretical research and practical studies and has been carried out using the following general methods:

1) literature and practical studies of image classification
2) surveys (case studies) about knowledge levels concerning image separation and color management in real world printing
3) semi-structured interviews
4) empirical studies of the use of adaptation in the process
5) creation and testing of new tools

- The literature studies have focused on image classification. Practical studies have been performed with different image categories, where the goal was to identify borders between the image categories. The lightness of the images was studied in the Adobe Photoshop and Matlab software. Test prints have been prepared on a sheet-offset press Heidelberg Speedmaster-74. Subsequently, the image category borders were used to create an IT.8 test chart for the print.

Two surveys dealing with knowledge levels concerning color separation were made between the years 2000 and 2004. The case studies are based on semi-structured interviews. Direct contact (e.g. e-mail, telephone calls and site visits) was established with printing facilities in order to assess the level of knowledge concerning color separation and the use of ICC-profiles in the graphic arts industry in Sweden.

- A third survey about demand specifications for controlled color reproduction was carried out in 2004. Thirty lithographic offset printers in Sweden (from north to south) were contacted by e-mail, telephone or personal visits to clarify their internal technical specifications relating to color management. The survey questions were prepared to define the demand for specifications between printing companies and external consultants, as well as internally between the prepress and press departments. The interviews were semi-structured.

Adaptation of the different parts of the process was studied. Test prints were prepared on a sheet-offset press Heidelberg Speedmaster-74. The test prints were used to investigate whether it is possible to adapt the test chart to the image category, and furthermore to investigate whether gray balance can be used in sheet-fed offset printing.

- The analysis of pedagogic facilitation of the processes for the users were based on the results of the investigations at selected printing houses. Creation of the educational tools was done in Adobe Illustrator and Adobe Photoshop.

Details on the methodology used in the different sub-studies are presented in the included papers.
4 Theoretical considerations

Color reproduction has been studied by many researchers. The elementary principles of color reproduction were described by Yule (Yule, 1967). The publication of Principles of Color Reproduction in 1967 was a landmark event in the evolution of photomechanical color reproduction theory and practice. “Here, for the first time, was a complete treatise on the scientific and technical aspects of color reproduction written specifically for the printing industry”, (Yule, 1967). Yule describes color reproduction, color vision, color measurement, color separation etc. The basis of under-color removal (UCR), a type of color separation, was also explained.

Hunt (Hunt, 1970) defined six different types of color reproduction: spectral, exact, colorimetric, equivalent, corresponding and preferred. Hunt’s explanation of these different ways of looking at color reproduction has a particular relevance to comparisons between original scenes and photographs (Field, 1990). Field described the objectives and strategies for color reproduction and for different image originals. The objectives of graphic arts color reproduction depend up on the type of original on the requirements of the print buyer, and on the expectations of the end user or consumer of the printed item (Field, 2004).

4.1 The need for image classification

Modern image processing involves many ways of reaching the final result, but image processing contains many steps which are being carried out manually without any clear rules. Without clear instructions from customers, pre-press personnel today must determine subjectively the category of the image, i.e. classify the image. Thus the personnel apply a subjective selection technique to achieve the highest possible quality on their image and on the final product. In order to retain important details in an image, the tone compression needs to be correctly controlled, but when this is carried out manually, the emphasis is on the tone area which one wants to retain to the greatest extent, i.e. to the area to be preferentially viewed in the image (for example an advertisement and its specific image). It is here that image classification is extremely important. In the treatment of images with, for example, details in dark areas, it is often necessary to retain more tones in these areas, with a possible loss of detail in bright areas as a consequence.


4.2 The need for a common terminology

A common terminology would make communication easier for all parties involved. It is extremely important to have the same terminology in order to avoid and minimize misunderstandings. Even basic concepts demand correct usage. Consider this example: The printer says that there is too little red in his image, when he really means that there is too little magenta in the print, but to a pre-press person, too little red could mean that there is too much cyan in the image. An adjustment in the image due to this misunderstanding might have a disastrous effect on the quality of the image. This unfortunate color “language barrier” is a result of there being no single standard to describe color (Green, MacDonald, 2002).

4.3 Images and image categories

The main area of interest in a photograph is the area on which the observer tends to center his attention and this generally contains the main subject or theme elements selected by the photographer. When the photographer prints the photograph he/she has a choice as to where on the scale of the photograph he will place the main interest area. Depending on aesthetic considerations and the desires of his/her client, the photographer may use either selected parts of or the entire tone scale. For example, he/she can place a subject on the highlight end of the tone scale, in which case it would be called “High Key”. Conversely, if he/she uses the shadow end of the tone scale it is called “Low Key”, and if he/she uses the entire tone scale it is called “Normal key”. (Jorgensen, 1987)

Images can be divided into different categories depending on their image content, key information and tone distribution. Some of the image categories currently mentioned in literature are: high-key, normal key, low-key (Field, 1990), gray balance and tertiary color images.

In Sweden, there is no standardized terminology for the different image categories, and this means that many different definitions appear. For images dominated by light tones, concepts such as high-key, “snow-image” and “light-image” are used. This can easily cause confusion, as some users think that “snow-images” are the same as winter-images. For dark images, concepts such as low-key, “night-image”, or “heavy-image” are used.

Image classification has been studied in Sweden by several researchers. In the 1980s, Olsson and Germundsson (Olsson, Germundsson, 1990) introduced definitions that
are still being used today. These definitions are “snow-image” and “night-image”. Examples of earlier definitions used in Sweden are “light image” and “heavy image” (Beckman, 1991).

The first documented use in offset press in Sweden of the use of different image categories (e.g. “light image” and “heavy image”) to evaluate the print result was in 1977 (Pappersgruppen, 1977). The definition of a light image was that most of the image content was found in the highlights and middle tone range, whereas the heavy image had its main content in the middle tone range and in the shadows.

4.3.1 Histogram of the image

Histograms are the key to understanding digital images, see example of a histogram in Figure 7. In this Figure the histogram shows how the 256 possible levels of brightness are distributed in the image. The histogram displays the tonal distribution of the pixels in the image based on their level of brightness, on the x-axis from dark (0) to light (255). The y-axis represents the total number of pixels in the image of each level of brightness. If the histogram has the peaks concentrated towards the side of the graph, this is a “low-key” image. It can also mean an under-exposed image. If the peaks are concentrated towards the right-hand side, the image is “high-key”, Figure 8. (Curtin, 2007)

![Histogram of the image](image)

Figure 7: The figure shows how to read a histogram (Curtin, 2007)
Most prosumer cameras and all professional cameras allow the user to view the histogram on the camera’s LCD (Bockaert, 2009). The following Figures 9-14 show examples of the different histograms of one picture depending on exposure and contrast:

- correctly exposed image, Figure 9
- underexposed image, Figure 10
- overexposed image, Figure 11
- image with too much contrast, Figure 12
- image with too little contrast, Figure 13
- image with modified contrast, Figure 14

Figure 8: Examples of a high-key image, a normal-key image and a low-key image (Royalty free images from Stockpix).
Theoretical considerations

Figure 9: This is an example of a correctly exposed image with a "good" histogram.

Figure 10: The histogram indicates there are a lot of pixels with value 0 or close to 0, which is an indication of "clipped shadows". Some shadow detail is lost forever.

Figure 11: The histogram indicates there are a lot of pixels with the value 255 or close to 255, which is an indication of "clipped highlights". Subtle highlight detail in the clouds is lost. There are also very few pixels in the shadow area. (Bockaert, 2009)

Figure 12: This image has both clipped shadows and highlights. The dynamic range of the scene is larger than the dynamic range of the camera. (Bockaert, 2009)
4.3.2 High-key images

High key: A photographic or printed image composed largely of lighter tones in which the main area interest lies in the highlight end of the scale (Field, 2004).

“Snow images” (Olsson, Germundsson, 1990) hold their main information in the high-key areas (lighter tones). The images that are considered to belong to this group are those where the bright areas fill up approximately 60-90% and the dark sections the remaining 10-40% of the total image. In snow-images, the important information to be viewed often lies in bright pastel colors and white shades. The differences in shades are extremely small. The difficulty with this type of image is that the shades approach each other during reproduction and are completely smoothened out in printing. The rougher the surface of a paper, the more the shades will deviate. The image adjustment through dot-gain control, wet-on-wet adjustment (trapping) and achromatic repro* must be somewhat lower than normal for the shade differences in the bright areas to appear more clearly. It is also important to decide where to set the “white point”, in order not to burn out details in the brightest section of the image. (Olsson, Germundsson, 1990).
4.3.3 Normal-key images
Normal key: A photographic or printed image in which the main area of interest is in the middle-tone range of the tone scale, or is distributed throughout the entire tone range (Field, 2004).

“Mid-tone images” (Olsson, Germundsson, 1990) have a tone distribution throughout the tone scale with the main information in the mid-tone section. This category is easy to reproduce since it holds information over a wide tone range. However, the mid-tones are subject to a large dot gain which needs to be compensated for. (www.naa.org)

4.3.4 Low-key images
“Night images” (Olsson, Germundsson, 1990). The main information to be viewed is found in the darker image tones.

Low-key images: A photographic or printed image composed largely of darker tones in which the main area of interest lies in the shadow end of the scale (Field, 2004)

4.3.5 Gray-balance images
“Gray-balance images” (Tidningsutgivarna, 1990). This category has its main information near neutral black. Conventionally, a black and white image would be reproduced in cyan, magenta and yellow (chromatic reproduction). A three color reproduction, without black, is more sensitive to color shifts in a print run because any shift in one of these results in perceivable deviations. A certain amount of black is usually added to stabilize the variations in the print run, which is a degree of achromatic reproduction* or gray component replacement (GCR*).

4.3.6 Tertiary color images
“Dirt images” (Tidningsutgivarna, 1990). A category where the three primaries (CMY) are dominant causing a tertiary color*, usually in the darker tone scale. The tones are closely distributed in the lower end of the color gamut*, and this makes it challenging to reproduce the tones correctly in order to avoid a flat reproduction. The difficulties are mainly due to dot-gain*, trapping* and relatively high ink coverage.
4.4 Tonal range and tone compression of images

The human eye can detect a wider tonal range than can be printed. It is not possible to reproduce the complete tonal range of an image in any printing process for many reasons, e.g. limitations in the photographic emulsion, photography using a digital camera, the characteristics of the paper and the limitation of the printing processes. The unsurpassed quality of the finest printed color reproduction is due largely to the properties of the substrate and inks used to produce the printed product (Field, 2004). The chosen paper quality affects the quality of the printed image, and the paper characteristics are of great importance for the print result (Johansson, Lundberg, Ryberg, 1998). The composition of the substrate, i.e. paper, as well as the surface treatment also limit the amount of ink which can be used. The amount of ink (and thus the print density), is therefore directly dependent on the paper. The higher the smoothness and the less absorbent the surface of the paper, the higher the print density that can be achieved. In offset, too high a total ink coverage (TIC*) can cause drying problems and this often results in dirty reproductions/prints (set-off*, rub-off) which in turn may delay the after-treatment and lead to diminished print quality. The TIC must therefore be well suited to the selected paper grade and to the choice of image separation control.

Tonal compression leads to a loss of image information. To be able to take the best possible advantage of the information in the original image, one should, during the scanning of the image, decide which areas of the image should be prioritized. Therefore, it is advisable to evaluate each image prior to scanning, and to decide which areas are of importance and which are not (Johansson, Lundberg, Ryberg, 1998).

Prior to the scanning of an image, one must consider how large a tone range can be printed on selected paper grades. Problems may arise if all images are treated in a similar manner regardless of what the image looks like and what motifs the image contains. The use of the same type of treatment for different images is often due to tight time schedules or to a lack of understanding.

Tonal compression necessarily leads to a loss of image information. In most cases, our eyes will not detect this loss of information, as our eyes concentrate upon the “important” areas of the image. To ensure that the reproduction is as similar as possible to the original, we must, already at the scanning stage, check how the tone compression is to be carried out and which areas of the image are to be given priority. In a generally dark image, i.e. a low-key image, the dark areas should be given priority.
so as not to lose tonal range in the shadows, and thus risk a decrease in the detail rendering. In a high-key image, the bright areas must be given priority. In a normal-key image, the middle tones must be given priority so that these are reproduced as well as possible. Low-key images should therefore be scanned with a high gamma-value and high-key images with a low gamma-value.

The electronic scanning of images captured on photographic films is now being used less and less in the printing industry, because most photographers are today using high resolution digital cameras. These cameras capture the images in RGB color space which is the standard in the display of digital images. The users cannot use the gamma value (such as in a scanning process) to correct the tonal range.

4.4.1 Tone reproduction
Tone reproduction is generally the most important aspect of color reproduction. The key requirement in tone reproduction is to find the best compression of the original densities which will consistently result in a high-quality printed reproduction. The compression should be uniform, emphasize highlights or shadows, or have other characteristics, Figure 15. The optimal tone reproduction curve is probably different for different originals and different people. (Field, 1990).

Figure 15: Estimated tone reproduction curves for transparency reproduction, showing interest area emphasis for high-key, normal, and low-key photographs. A is a curve for the high-key image, B for the normal-key image and C for the low-key image (Field, 1990).
George Jorgensen conducted research on tone reproduction for black and white originals. He found that the preferred curve varied according to whether the photograph was high key or normal (Field, 1990). Jorgensen’s investigations included different observers and different main areas of interest. Some of his conclusions (Jorgensen, 1987) are:

- if the main area of interest is in the highlight end of the print’s tone scale, the observer prefers a different tone reproduction curve than when his main interest area is in the middle tones or shadows

- there may be more than a single main area of interest in a photograph and the area selected by the viewer will depend on his interests, taste or bias. The difference in personal viewpoints may preclude a single best or optimum tone reproduction curve for a given photograph

Jorgensen’s research concluded that a tone reproduction curve emphasizing the “area of interest” of the photograph gives the best result (Field, 1990).

4.5. Situation today – digital cameras

Today’s widespread use of digital cameras means that customers bring their own digital material instead of material prepared by hired professionals. This means varying quality, which may in turn lead to problems later in the process. Most users today struggle to enhance the quality of their images.

The development of digital cameras has increased the number of RGB-images handled and thereby significantly decreased the use of image scanners by the printer. The tone compression is different when digital cameras are used, because the scanning process has disappeared. When scanning, it was necessary to consider the different image categories in order to highlight different areas in an image by adjusting the gamma settings (gamma curve), but digital cameras work in another way. In order to be able to take into account the important details (and thereby the different image categories) present in different areas of an image, it is necessary to know how digital cameras work and to understand which format best holds the information about the image.

Digital camera sensors respond to light quite differently from both the human eye and a film. Most of our human senses display a significant compressive non-linearity
– a built-in compression which makes it possible for us to function in a wide range of situations without driving our sensory mechanisms into overload. The sensors in digital cameras lack the compressive nonlinearity typical of human perception; they simply count photons and assign a tonal value in direct proportion to the number of photons detected – i.e. they respond linearly to incoming light. This means that if a camera uses 12 bits to encode the captured image into 4,096 levels, then level 2,048 represents half the number of photons recorded at level 4,096. This is what is meant by a linear gamma – the levels correspond exactly to the number of photons captured. Linear capture has important implications for exposure. If a camera captures information in six stops over the dynamic range, half of the 4,096 levels are included in the brightest stop, half of the remainder (1,024 levels) are included in the next stop, half of the remainder (512 levels) are included in the next stop, and so on. The darkest stop, the extreme shadows, is included by only 64 levels - Figure 16, so that correct exposure is very important for the quality. Figure 17 shows approximately how we see the same six stops. (Fraser, 2005)

4.5.1 The formats
If one uses a digital camera, it is of great importance to know in what format to save the images, in order to control and retain all of the image information. Today, the two main formats are: JPEG* (Joint Photography Expert Groups) and Digital Raw Format (but the TIFF* format also occurs).
Theoretical considerations

A raw digital file is a record of the raw sensor data captured by the camera. Different camera vendors encode the raw data in different ways, applying different compression strategies, and in some cases they even use encryption, so it is important to realize that digital camera raw data are not a single file format. (Fraser, 2005)

The raw file includes everything that the camera can capture and the user has some control over the interpretation of the image. When the user shoots JPEG, he/she trusts the on-camera settings and the camera’s built-in conversions which discard one-third of the data in a way that does justice to the image (the JPEG format is limited to 8 bits per channel per pixel). (Fraser, 2005)

If you save the raw data, you can convert it later to a viewable JPEG or TIFF file on a computer. The process is shown in Figure 18.

![Diagram](https://via.placeholder.com/150)

Figure 18: The process for the different formats. (Atkins, 2009)

**JPEG**

If the data is stored as a JPEG file, it goes through the Bayer interpolation*, it is modified by in-camera set parameters such as white balance, saturation, sharpness, contrast, etc, it is subject to JPEG compression, and then it is stored. The advantage of saving data in a JPEG file is that the file size is smaller and the file can be directly read by many programs or even sent directly to a printer. The disadvantage is that there is a quality loss, the amount of loss depending on how much compression is used. The greater the compression, the smaller the file but the lower the image quality. Lightly compressed JPEG files can, however, save a significant amount of space and lose very little quality. (Atkins, 2009)

**Raw**

The first advantage of saving raw data is that the user can choose the white balance, contrast, saturation, sharpness, etc. he/she wants. The user can change many of the shooting parameters after exposure, but the user cannot change the exposure and he/she cannot change the ISO setting, but he/she
can change many other parameters. A second advantage of saving a raw file is that the user can also convert the data to an 8-bit or 16-bit TIFF file. TIFF files are larger than JPEG files, but they retain the full quality of the image. They can be compressed or uncompressed, but the compression scheme is lossless, meaning that although the file becomes smaller, no information is lost. (Atkins, 2009)

4.6 The standardization of the printing process
A better communication between all involved parties in graphic production is needed for an optimal printing of every image, regardless of image category. One possible way of improving the communication can be standardization and color management.

Standards are publicly accessible documents for the manufacture of products and systems which are made binding through national and international agreements. Standards create a common language between all parties involved, between manufacturers and users, between customers and suppliers. Yet standards also create production stability within a company due to clearly structured workflows. Successful standardization brings cost reduction in daily production and improves quality with fewer customer complaints. (Bestman, 2006).

Standardization for the printing industry secures profitability and technical progress worldwide. On the technical side, standards make important contributions to the clear communication between producer and user, particularly as concerns technical specifications and interface description for production process. (Dolezalek, 2004)

Recently, the use of standards has been increasingly appreciated. The standards provide a framework for the production. During the 90s, "Kvalitetshandboken" (The Quality Manual) was published and in its latest edition, the 4th, (Klaman, Andersson, 2003) gave recommendations for offset printing in Sweden. This work has proven important for printing companies in Sweden. The recommendations and target values in this quality manual are based on ISO standards.

The International Organization of Standardization (ISO) maintains many international standards, including those concerning color management, photography and printing. There are different "Technical Committees" (TCs) responsible for different fields. Concerning color management and printing, TC 130 is the most important committee. TC 130 maintains the following ISO standards:
Theoretical considerations

ISO 12640 Input data for characterization of 4-colour process printing
ISO 12642 SCID (standard colour image data) images
ISO 12647 process control for the manufacture of halftone colour separations, proof and production prints
ISO 13655 spectral measurement and colorimetric computation for graphic arts images
ISO 15076 ICC colour management
ISO 15930 Prepress data exchange PDF/X (Colorwiki, 2007)

For an overview of the formal and informal standards in the graphic industry see Figure 19. "De facto standard" is the standard which has arisen as a result of the development of a stable and healthy market (GFF, 2008). Also a dominant company on the market, such as Adobe, can have an impact on usage of settings which can count to ”de facto standard”. For example RGB working space in Adobe applications is Adobe RGB (1998) and this setting is ”de facto standard” on the market for the users.

In the graphic printing industry ISO Standard 12647 is used. The tools (concerning color management), such as Altona Suite (see 4.6.4), which are on the market are adapted to this standard. The description of this ISO Standard 12647 follows in the next chapter.

<table>
<thead>
<tr>
<th>Formal standards and specifications</th>
<th>Informal standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>accredited standards</strong></td>
<td><strong>de facto-standard</strong></td>
</tr>
<tr>
<td>Developed through consensus processes in international or national standardizing bodies.</td>
<td>Non-formal industry standard that has emerged on the market.</td>
</tr>
<tr>
<td>Example: ISO 12647-2</td>
<td>Example: - the use of ISOcoated v2 as a standard separation profile for sheet-fed offset - the use of PDF as document format</td>
</tr>
<tr>
<td><strong>industry standard or specification</strong></td>
<td><strong>supplier specification</strong></td>
</tr>
<tr>
<td>Formalized and detailed description of the activities necessary to fulfill a standard.</td>
<td>Reference values for a certain printing condition: Complete colorimetric description of a printing condition in the values of characterization data (measured test form for the generation of ICC-profiles i.e. EC2002)</td>
</tr>
<tr>
<td>Example: - ProzessStandard OffsetDruck (PSO), Germany - GRACol, USA - Certified Grafisk Produktion, Sweden</td>
<td>Example: - Pantone PMS and Pantone Goe - System Brunner</td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 19: Overview of the formal and informal standards and specifications concerning printing. (GFF, 2009)
4.6.1 ISO Standard 12647

This chapter will give a background information about the ISO printing standard in broad outline. The ISO 12647 consists of the following parts, under general title

*Graphic technology – Process control for the production of half-tone colour separation, proof and production prints:*

- **Part 1. Parameters and measurement methods**

ISO 12647-1:2004 specifies parameters which define printing conditions for the various processes used in the graphic arts industry. Practitioners wishing to work towards common goals may use the values of the parameters specified in the exchange of data to characterize the intended printing condition and/or for the process control of printing. (ISO, 2009)

- **Part 2: Offset lithographic processes**

ISO 12647-2:2004 specifies a number of process parameters and their values to be applied when preparing colour separations for four-colour offset printing or when producing four-colour prints by one of the following methods: heat-set web, sheet-fed or continuous forms process printing, or proofing for one of these processes; or offset proofing for half-tone gravure. The parameters and values are chosen in view of the complete process covering the process stages colour separation, film setting, making of the printing forms, proof production, production printing and surface finishing. (ISO, 2009)

ISO 12647-2:2004 is

- directly applicable to proofing and printing processes which use colour separation films as input;
- directly applicable to proofing and printing from printing forms produced by filmless methods as long as direct analogies to film production systems are maintained;
- applicable to proofing and printing with more than four process colours as long as direct analogies to four-colour printing are maintained, such as for data and screening, for print substrates and printing parameters;
- applicable by analogy to line screens and non-periodic screens. (ISO, 2009)
Theoretical considerations

– **Part 3: Coldset offset lithography and letterpress on newsprint**
  ISO 12647-3:2005 specifies a number of process parameters and their values to be applied when preparing colour separations for single or four-colour newspaper printing and proofing. The parameters and values are chosen in consideration of the complete process, covering the process stages: colour separation, film setting, making of the printing form, proof production and production printing (ISO, 2009).

– **Part 4: Publication gravure printing**
  ISO 12647-4:2005 specifies a number of process parameters and their values to be applied to four-colour publication gravure printing. The parameters and values are chosen in view of the complete process covering the process stages colour separation, making of the printing form, proof production and production printing (ISO, 2009).

– **Part 5: Screen printing**
  This part of ISO 12647 specifies a number of process parameters and their values to be applied when preparing colour separations for four-colour screen process printing when producing four-colour proof and production prints by flat bed or cylinder screen printing (ISO, 2009).

– **Part 6: Flexographic printing**
  ISO 12647-6:2006 specifies a number of process parameters and their values to be applied to four-colour process printing by the flexographic printing process for packaging and publication, excluding newsprinting. The parameters and values are chosen in view of the complete process covering the process stages “colour separation”, “film setting”, “making of the printing form”, “proof production”, “production printing” and “surface finishing”. This covers printing on printing substrates which are nearly white or on films to which a white coating has been applied (ISO, 2009).

– **Part 7: Proofing processes working directly from digital data**
  ISO 12647-7:2007 specifies requirements for systems which are used to produce hard-copy digital proof prints intended to simulate a printing condition defined by a set of characterization data. Recommendations are provided with regard to appropriate test methods associated with these requirements. In addition, guidance with respect to the certification of proofing systems related to specific printing condition aims is also included. (ISO, 2009)
The ISO standard 12647 refers to the other standards that should be considered as a whole or partly in order to meet requirements in 12647 (GFF, 2008), see Figure 20:

**ISO 12647**
- ISO 12647-1:2004
- ISO 12647-2:2004
- ISO 12647-7:2007

**ISO 9000 Quality management systems**
ISO 9000 is a generic name given to a family of standards developed to provide a framework around which a quality management system can effectively be implemented.

**ISO 15930 Graphic technology - Prepress digital data exchange**
This ISO norm describes the requirements for PDF data being delivered to the printers. (Homann, 2009)
ISO 12646 *Graphic technology - Displays for colour proofing - Characteristics and viewing conditions*

ISO 12646:2008 specifies the minimum requirements for the properties of displays to be used for soft proofing of colour images. Included are requirements for uniformity, convergence, refresh rate, display diagonal size, spatial resolution and glare of the screen surface. The dependence of colorimetric properties on the electrical drive signals and viewing direction, especially for flat panel displays, is also specified. (ISO, 2009)

ISO 3664 *Graphic technology and photography - Viewing conditions*

ISO 3664:2009 specifies viewing conditions for images on both reflective and transmissive media, such as prints (both photographic and photomechanical) and transparencies, as well as images displayed in isolation on colour monitors (ISO, 2009).

ISO 3664:2009 applies in particular to:

• critical comparison between transparencies, reflection photographic or photomechanical prints and/or other objects or images;
• appraisal of the tone reproduction and colourfulness of prints and transparencies at illumination levels similar to those for practical use, including routine inspection;
• critical appraisal of transparencies which are viewed by projection, for comparison with prints, objects or other reproductions;
• appraisal of images on colour monitors which are not viewed in comparison to any form of hardcopy.

ISO 3664:2009 is not applicable to unprinted papers. (ISO, 2009)

ISO 13655 *Graphic technology - Spectral measurement and colorimetric computation for graphic arts images*

This International Standard establishes a methodology for reflection and transmission spectral measurement and colorimetric parameter computation for graphic arts images. Graphic arts includes, but is not limited to, the preparation of material for, and volume production by, production printing processes which include offset lithography, letterpress, flexography, gravure and screen printing. (ISO, 2009)
The ISO supports also the process color and density measurements:

**ISO 2846-1:2006** specifies the colour and transparency characteristics that have to be met by each ink in a process colour ink set intended for proof and production printing using offset lithography. The specified printing conditions (which use a laboratory printability tester), the defined substrate and a method for testing to ensure conformance are also defined. Characteristics are specified for inks used for sheet-fed, heat-set web and radiation-curing processes. (ISO, 2009)


4.6.2 Paper, density, dot gain and gray balance in ISO 12647-2
According to ISO standard 12647-2 there are five different paper types: gloss and matt coated, LWC, uncoated and uncoated yellowish paper, Figure 21.

![Table of CIELAB coordinates, gloss, ISO brightness and tolerances for typical paper types](ISO 12647-2:2004)

**Density**
As offset printing uses a mixture of ink and water, the printing process is subject to unavoidable fluctuations. These are a result of the interaction between paper, ink, water additives, climatization, the condition of the machinery, etc. The printer at the machine needs to compensate for these fluctuations so that the result matches that of the provided proof. He
achieves this by slightly varying the ink-layer thickness (solid density) for each individual printing color. For this reason, among others, there are no explicit target values in ISO 12647 for the solid density of individual paper types. (Homann, 2009)

**Dot Gain / TVI**
The dot gain (Tone -Value Increase, TVI) specifies how much higher the area coverage is on the paper compared to the file. As dot gain is dependent on a number of parameters, ideal dot gain and tolerances of ±4% are predefined in ISO 12647-2, in the mid-tones. Generally, the rule applies that dot gain of the colors cyan, magenta and yellow should be the same and black in the mid-tone should be 3% above the chromatic colors. The maximum spread indicates that the dot gain of the different colors should not differ by more than 5%. (Homann, 2009)

ISO 12647-2:2005: the tone-value increase of black ink is found to be equal or up to 3% higher in the mid-tone than that of a chromatic primary colour ink because black is usually printed on the first press unit and often, especially in sheet-fed offset, at a greater ink film thickness (ISO; 2009).

**Gray balance according to ISO 12647**
The gray balance in the print denotes a well-balanced ratio of the print colors cyan, magenta, and yellow, by which, in the combined printing of these colors, a neutral gray tone is produced. The ISO norm itself has neither explicit target values nor tolerances for the gray balance. (Homann, 2009). The ISO standard has an appendix with an "informative" part about gray balance, Figure 22.

<table>
<thead>
<tr>
<th>Tone value</th>
<th>Colour</th>
<th>Cyan</th>
<th>Magenta</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter tone</td>
<td></td>
<td>25</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Mid-tone</td>
<td></td>
<td>50</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Three-quarter tone</td>
<td></td>
<td>75</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

Figure 22: "Informative" information for CMYK values for use in gray balance patches. (ISO 12647-2:2005, Annex C)
ISO 12647-2:2004: *The specification of gray balance condition is redundant if the aim values for the tone-value increase and the coloration of the solids are specified. With the aid of colour-management profiles which are based on a given printing condition and its characterization table according ISO 12642:1996, the grey balance conditions are accessible. A single gray balance condition is usually not sufficient to ensure an achromatic colour for all print substrate and printing inks which are used for a given printing condition. In addition, it usually depends on the particular black composition used.*

### 4.6.3 Standards which are relevant to color management

Standards which are relevant to color management (Homann, 2009) are:

- **ISO 12647** *for Separation, Proof and Print*

- **ISO 12642** *for test charts to create profiles*

  In this standard the composition of the test charts to create color profiles is predefined. If the charts of this predefined standard are printed and measured, these measured values can be used to create profiles with all programs which support these charts. (Homann, 2009). Figure 23 shows the test chart ECI 2002 in visual and random layouts. The third test chart is the classic test chart IT 8/7.3.

- **ISO 12640** *for characterization data*

  ISO 12640 predefines in which form the color-measurement data from the ISO 12642 test chart should be saved after measuring.

- **ISO 15076 / ICC** for color profiles

  This part of ISO 15076 specifies a colour profile format and describes the architecture within which it can operate. This supports the exchange of information which specifies the intended colour image processing of digi-
tal data. Specification of the required reference colour spaces and the data structures (tags) are included (SIS; 2009).

ISO 15930 PDF/X
This ISO norm describes the requirements of PDF data being delivered to the printers.

4.6.4 Tools surrounding ISO 12647
There are some tools connected to the ISO standard 12647. These tools help to control the printing quality and to achieve good communication with all involved parts.

The tools are (Homann, 2009):

- Reference Prints from Altona Test Suite (bvdm. 2009)
  Altona Test Suite (Online Version and Application Kit) is a joint project of German Printing and Media Industries Federation (bvdm) Wiesbaden, European Color Initiative (ECI), Ugra St. Gallen, Switzerland and Fogra Graphic Technology Research Association Munich Germany. With the Application Kit important new tools and data are provided for the user for standard process control, quality check and and workflow test. The Application Kit contains reference prints, test suite files, characterisation data and ICC profiles according to the latest values of ISO 12647–2 Standard process control (offset). (UGRA, 2009). See Figure 24.

- characterization data from FOGRA
  At www.fogra.org FOGRA offers free characterization data based on the Altona Test Suite. See example of FOGRA characterization data with the different paper types and the ICC-profiles from ECI (European Color Initiative) and Adobe in Figure 25.

- the Ugra/FOGRA Medias wedge CMYK V3.0,
  The Ugra/Fogra Media Wedge CMYK is the standard tool for the control of the color transformation from the data to the digital proof or the printing, Figure 26. With the Ugra/Fogra Media Wedge CMYK the aim values for standard print procedures and paper types are supplied. The wedge consists of 72 patches, which are defined with area coverages of the process
colors C (Cyan), M (Magenta), Y (Yellow) and K (Black). For each patch, colorimetric aim values according to ISO 12647 are defined, depending on the printing procedure and the printing substrate. (UGRA, 2009)

Figure 24: The Altona Suite Application Kit. (bvdm, 2009)

<table>
<thead>
<tr>
<th>Paper type, PT</th>
<th>characterization data</th>
<th>ICC-profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT1+2 Coated</td>
<td>Fogra 39</td>
<td>From ECI: ISO Coated v2(ECI)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From Adobe: Coated Fogra 39</td>
</tr>
<tr>
<td>PT3, LWC paper</td>
<td>Fogra 46</td>
<td>PSO_LWC_Standard_eci</td>
</tr>
<tr>
<td>PT3, &quot;Improved&quot; LWC paper</td>
<td>Fogra 45</td>
<td>PSO_LWC_Improved_eci</td>
</tr>
<tr>
<td>PT4, uncoated paper</td>
<td>Fogra 47</td>
<td>PSO_Uncoated_ISO12647_eci</td>
</tr>
<tr>
<td>PT5, uncoated, yellowish paper</td>
<td>Fogra 30</td>
<td>ISO Uncoated Yellowish</td>
</tr>
</tbody>
</table>

Figure 25: ISO paper types according to ISO 12647. (GFF, 2009)
PSEO= Process Standard Offset
4.6.5 GRACol, SWOP and gray balance

The North American specifications GRACol and SWOP are compatible with ISO 12647.

SWOP = Specifications for Web Offset Publications
- is an organization of industry enterprises concerned with specifications for data, proof and print control for web offset printing
- the SWOP characterization data corresponds to the offset print calibrated in accordance with the G7 methodology (Homann, 2009)

GRACol = General Requirement for Applications in Commercial offset Lithography
- mainly guidelines and specifications for data, proofs and print control in sheet-fed offset printing
- the GRACol characterization data corresponds to the offset print calibrated in accordance with the G7 methodology
- in 1996, a graphic arts task force was formed by the Graphic Communications Association (now IDEAlliance) to develop a document containing general guidelines and recommendations that could be used as a reference source across the industry for quality color printing. Since that time, the GRACol Working Group has developed, maintained and published printing guidelines which have since become de facto standards on many pressrooms. The mission of GRACol is to improve communications and education in the graphic arts field by developing best practices which reflect the influence and impact of new technologies in the workflow of commercial offset lithography. GRACoL is a registered trademark of IDEAlliance. (IDEAlliance, 2009)

The IDEAlliance is an umbrella organization under which the further development of SWOP and GRACoL, among others, is co-ordinated
- IDEAlliance (International Digital Enterprise Alliance) is a not-for-profit
membership organization which has been a leader in information technology and publishing since 1966.
- This organization has recommended the G7 method for the calibration of offset printing processes, which is not based on ISO 12647-2

G7 method

- G7 is a Specification defined by the Print Properties and Colorimetrics Working Group of IDEAlliance. Initially G7 was developed by the IDEAlliance GRACoL Working Group (IDEAlliance, 2009).
- G7 is a new calibration method developed to support the GRACoL 7 specification. The 'G' refers to calibrating Gray values, while the '7' refers to the seven primary color values defined in the ISO 12647-2 printing standard; Cyan, Magenta, Yellow, Black (K), Red (M+Y), Green (C+Y) and Blue (C+M). Although originally intended for commercial offset printing, the G7 method is applicable to virtually any CMYK imaging process, and has been successfully tested on a wide range of processes, including coated and uncoated offset, newsprint, gravure, flexography, dye-sublimation, ink-jet, and electrophotography, as well as a wide range of AM and FM screening methods. (IDEAlliance, 2006).
- The main benefit of G7 over traditional calibration methods is a more constant gray scale appearance. This is partly because G7 defines gray balance in CIELab terms, instead of by arbitrary CMY TVI (Tone Value Increase) curves, and partly because the visually-critical highlight contrast of a neutral gray scale is defined in direct neutral density units, rather than by CMY TVI curves (IDEAlliance, 2007).

- IDEAlliance published a control strip in November 2007 and this is based on ISO 12647-7, Figure 27. This is an American equivalent to the FOGRA/UGRA media wedge CMYK. At that time there was no obligatory tolerances for the evaluation of this strip (Homann, 2009).

Figure 27: IDEAlliance 12647-7 Control Strip 2007
**FOGRA/ISO 12647-2 versus G7**

A comparison between the methods of FOGRA/ISO 12647-2 and G7 for calibration and process control of offset printing to match the standardized digital proof shows that there are fundamental differences, Figure 28. The aim of the FOGRA method is to achieve the best possible dot gains in ISO 12647-2. Today, the dot gain only plays a very marginal role in G7 for offset printing.

G7 contains a manufacture-independent method for measuring the gray balance as well as lightness in the mid-tones in the ongoing production. At present (2009), the methodology of FOGRA/ISO 12647-2 needs be included in this area. (Homann, 2009).

**FOGRA Die Fogra Forschungsgesellschaft Druck e.V.**

= Fogra Graphic Technology Research Association
- the objective of Fogra is to promote print engineering and its future-oriented technologies in the fields of research, development and application, and to enable the printing industry to utilize the results of this activity.
- the eight Technical Committees, responsible for various specialist topics, are a central part of Fogra. In these committees, specialists from printing businesses, and Fogra staff, define industry problems to be studied. (FOGRA, 2009)
Discussion in ISO TC 130 about G7

The Technical Committee 130 is the international working group which develops the ISO standards for the graphics industry and adapts them for the latest technical status. Many European representatives regard the G7 methodology as competition for the ISO standardization, because in the USA printers are certified as G7 Master Printers on an international level, see Figure 29.

On the other hand, in the USA people see the G7 as an American interpretation of ISO 12647, because it complements in important criteria such as a more exact metrological definition of the gray balance in production. (Homann, 2009)

4.6.6 Standardization versus adaptation

Standardization is essentially an act of simplification, as a result of the conscious effort of society. It not only results in the reduction of complexity but also aims at the prevention of unnecessary complexity in the future. Standardization is a social as well as an economic activity and is be promoted by the mutual cooperation of all concerned. “The activity of standardization results in a recorded and agreed document based on a general agreement”. (Sanders, 1972)

The standardization of printing processes according to ISO 12647 is established worldwide today. Ten years after the first publication of the ISO 12647-2 standard for offset printing, methods, applications and tools are well established and used with great success by customers, service providers and printers. For all printing processes, characterization data and profiles adapted to the standard are available as well as comprehensive tools for application at all process stages from data generation to the print run. (bvdm, 2006).

However, there is no conflict between standardization and adaptation. The standardization is a broader concept than adaptation. The printing company can adapt their parts of the production (adaptation of the scanner test chart or of the printing test chart) and thus can get an improvement in the quality. The adaptation can be done within the limits of the standard. If the printing company wants to customize/adapt, it must have an good understanding of the processes.
Theoretical considerations

If the printing company decides to print according to printing standards (without any specific adaptation such as adaptation of the printing test chart), the company still must adapt some parts of the production in some way to come within the limits of the standard (for example size of tone value increase). This problem relates to research area 3 of this thesis.
Summary of original work
5 Summary of original work

5.1 Paper I, TAGA 2003, Montreal, Canada
“Image Classification and Optimized Image Reproduction”

5.1.1 Introduction
ICC-profiles are being used more and more frequently to predict the rendering of colors and thereby ensure a high quality. An ICC-profile is a data file describing the color characteristics of an imaging device (Sharma, 2004). The primary purpose or use of this file is to maintain color consistency in images viewed, displayed or printed on various devices (Wallner, 2000). By using a common format (ICC, International Color Consortium) for characterization of color units, it is easier to determine the color gamut of a device and thereby optimize a print-out. A device is characterized by printing and measuring target values in a color chart. There are a large number of different color charts on the market, all of which are assumed to be valid for all types of images, no matter whether the relevant image information is located in high-key areas, low-key areas or mid-tones. The result is that too few color tones containing key image information can be analyzed. In the work described in Paper I, new adapted color charts were created based on technical and visual image category analysis. A number of tests have been carried out using extreme images with their key information strictly in the dark or light areas. The results show that the image categorization using the adapted color charts improves the analysis of relevant image information with regard to both image gradation and detail reproduction. The new adapted color charts preserve details in the low-key areas, and give a more distinct image with a better fidelity to the original image. Evaluations have been made using a test panel and the pair-comparison method.

5.1.2 Objective
The purpose of this work was to study if the categorization of images can improve the quality of color reproduction by adapting standard color charts.

This study relates to research area 3 of this thesis.

5.1.3 Method
Test charts commonly used for output characterization were studied to evaluate how the tone steps are distributed for output characterization, and a new set of color values was used to create an image-adapted test chart, different from the gamma and gradation values normally used. These category-adapted test charts were printed under
controlled conditions. Spectral measurements were made on the new test charts, and new output profiles were calculated and applied in the RGB-to-CMYK conversion for the specific image category aimed for. A validation print was made with the new separation values applied to the specific image category aimed for. The results were evaluated by the subjective pair-comparison method, where 50 people with a graphic arts background judged the result. An objective evaluation was made by instrument measurements of lightness values.

5.1.4 Background to the creation of an image category border
- classification using L*-values
In order to establish more distinct borders between the different image categories, tests were carried out with L*-values (L= lightness). Initially, 30 digital color images from each category were selected together with Björn Olsson (who introduced Swedish definitions for different image categories), Figure 30.

Figure 30 : Examples of a high-key, a normal-key and a low-key image. (Royalty free images from Stockpix - the lower row)
The distribution of the L*-value in the three types of images indicates the borders that may exist between these images, Figure 31.

![Distribution of L*-value](image)

**Figure 31**: Distribution of L*-value for high-key, normal-key and low-key images. The peak for high L-values in the normal-key image is caused by the white background. The graph was created in Matlab (Enoksson, 2001).

The images were processed in Adobe Photoshop, where the color information was discarded in order to analyze only the L*-values. The images as well as their histograms were studied and analyzed using the Matlab-software, Figure 32.
Figure 32: The steps made in the Matlab analysis. Number of pixels in different steps of $L^*$ scale in high-key image. The steps made it possible to find the borders between the images.
The borders of the L*-values for the different image types were used to create an image-adapted color chart.

Each image category was printed in an offset press, Heidelberg Speedmaster 74, on a coated (130g/m²) and an uncoated (130g/m²) paper. The prints were processed and separated using Adobe Photoshop, where the color information in the images was compressed against adjacent colors, turning them into an IT.8-target (24x18 patches) for easier measurement, Figure 33.

![Figure 33: Adapting of the image (normal-key) to an IT.8 target, 24x18 patches.](image)

The patches of the images were measured using a spectrophotometer and the CIELab L*-value was computed. The measured values were used to compare the three image categories the L*-values in the original data and the L*-values on coated and uncoated papers, Figure 34. The Figure clearly shows that the scatter of the L*-values in the images was compressed by the different paper grades. On an uncoated paper, the dark areas are clearly lighter, which means that there is a poorer detail rendering in the printing.
5.1.5 Results - Image classification by using L-values
The studies of the three image categories (high-key, low-key, normal-key) revealed that the borders in the L*-scale for high-key images were 100-60, for normal-key images 60-40, and for low-key images 40-0, Figure 35.

Figure 34: Distribution of L*-values for a normal-key image and for prints on coated and uncoated paper.

Figure 35: The borders in the L*-scale (Lightness) for high-key, normal-key and low-key images (Paper I).
5.1.6 The image adapting of the test chart

Are there other solutions which will make it easier to give priority to interesting areas than is usually done by tonal compression or optimal separation (GCR - Gray component Replacement, UCR - Under Color Removal)? The beginning and the end of the production chain both offer an adaptation to the production and method of giving priority to certain image categories and areas of an image.

Each part of the graphics industry has high demands on color reproduction and the demands of the print buyers and end users for quality are steadily increasing. Color communication between scanners, computers and output devices has improved, thanks to ICC-profiles. There are several companies developing software for profiles on the market. Each of these products is designed to help the user achieve improved color fidelity, each one looks and works differently and may produce different results (Adams II, 2000). Each software has its own color test chart. Test charts differ from each other in the number of color patches, the values of the patches and the color distribution. The test charts have one thing in common - they are intended to work for any kind of images with no focus on any particular image category.

The hypothesis in this Paper I has been that it is possible to adapt the test chart to the image category and thus give priority to sections of the tonal range. Tests of this hypothesis have revealed that there are two ways to adapt the test chart:

- a) to create a new adapted test chart
- b) to adapt the standard test chart

a) Creation of a new adapted test chart
The borders suggested in Figure 35 were used to create a new image-adapted test chart, as shown in Figure 36. For some patches, the Neugebauer equations have been used.
The construction of the test charts available on the market was studied and the values of these test charts were measured and compared (Paper I). The new test charts were created based on the suggested borders between image tone values, Figure 32. The distribution of the values generates a slope which can be compared to a gamma curve for the different image types (Paper I).

b) Adapting of the standard test chart
Another way of adapting the test charts is to adapt the standard test chart. The same knowledge about the gradation from the previous study was used. The standard test chart 6.02 was adapted in software AdobePhotoshop (Paper I).

5.1.7 Results - adapting the IT8. test chart for printing
A new printing was carried out (Heidelberg Speedmaster 74) using these test charts and subjective and objective evaluation of the prints were carried out:

• the subjective evaluation used 50 people from the graphic industry and from the Graphic Institute. A paired comparison (Bristow, Johansson, 1983) was made of the prints. People involved in this evaluation preferred the prints which were based on separations with the adapted test charts, Figure 37.
• for the objective evaluation, gray scales were created in Adobe Photoshop and separated with the same profiles as for the images. The gray scale which was based on a separation with the adapted test chart showed more detail in the dark tones.

**Subjective evaluation: low-key images**

![Graph showing comparison of subjective evaluation scores](image_url)

Figure 37: The result of the subjective evaluation. The y-axis shows the points for the test charts (Paper I)

The low-key prints which were based on a separation with the image-adapted test chart showed more detail in the dark areas, as can be seen in Figure 38.

![Comparison of low-key images](image_url)

Figure 38: A comparison between low-key images after printing. The image to the left was separated with the standard test chart and the image to the right with the image-adapted test chart.
5.1.8 Conclusion
The results suggest that an adjustment only to low-key images is sufficient, as even normal-key prints then show a better fidelity to the original image. High-key images show no difference between the different IT.8 test charts, Figure 39. Classifying images is a difficult task, as it is the customer who should ultimately decide which areas of an image are most important. The general reasoning that high-key images have the greatest concentration of information in the bright areas, normal-key images in the middle-tone areas, and low-key images in the dark areas of the tone scale is quite reasonable. An “exact” mathematical definition can be produced, but it loses its value directly for the graphics industry (because of the different needs of the users) as it does not help in the actual image processing. An analysis of the pixel numbers in an image in the L*-scale generates suggested borders which can be applied in further studies. These borders make it possible to adapt the IT.8 test chart for printing with improved results. IT.8 test charts for scanners also permit a certain adaptation for production or for specific colors.

The ideas and methods concerning the adaptation of IT.8 test charts is the subject of a application, where a Swedish patent has already been granted. (Enoksson, 2004). No similar work was found by the patent office.

5.1.9 Comments
The test form for printing the IT.8 test charts can be complemented with a compensation of the test chart, e.g. the method published by Nordström (Nordström, 2003), in order to achieve the optimal ink coverage in the particular printing press.

Tests with the adapted test charts have also been performed with an ink-jet printer, HP Designjet 5500. (Åman, Lind, 2004). The results of these tests also suggest that the adapt test chart leads to a higher detail level in the dark areas of a low-key image.

There are also other parameters which can impact on print quality. The quality of a color print is not established simply by the hue, saturation, and lightness of individual areas; image definition (resolution and sharpness) factors also play a significant role (Field, 2001).
The low-key image showed more details in dark areas.

Normal-key image showed a better agreement with the originals.

High-key image - no distinctions among them could be observed.

Figure 39 The low-key image showed more details in dark areas. Normal-key image showed a better agreement with the originals. High-key image - no distinctions among them could be observed.
5.2 Paper II, VI.Polygraficky seminar, 2003, Pardubice, Czech Republic

“The characterization of input devices by luminance and chrominance”

5.2.1 Introduction
Both the beginning and the end of the production chain offer possibilities for an adaptation for one’s own production and to give priority to certain image categories and areas in an image. The beginning of the process is the creation of the scanner profile with the special test chart for the scanner.

5.2.2 Objective
The aim of this study was to evaluate how different IT8-test charts for scanners correlate with each other, with the ISO-standard, and with different RGB color working spaces used in imaging applications. Each scanner chart holds a specific gamut of colors for a scanner to capture. If a flatbed scanner can precisely scan each color patch colorimetrically correctly, then a scanner profile (ICC) would not be necessary. However, each color which is incorrectly scanned according to its colorimetric value will need a color correction when being converted from the source profile (scanner) to the destination profile (RGB color working space).

This study relates to research area 3 of this thesis.

5.2.3 Method
The scanner profiles capability can be evaluated by using a test image with a few known color values with high chroma. The result can be evaluated according to known color values. Three IT8.7/2 test targets were used in the test. Besides the established IT8-targets from the major color chart vendors a new IT8-target was created for the tests. The four test charts are named A, B, C and D in the study. Reference color values such as lightness and chroma coordinates were read from the test targets. A spectrophotometer was used for the readings.

The following seven stages describe the tests performed:
1) Comparison of the different input profiles (A, B, C), with raw scanning (gamma 1) and gamma 2
2) Comparison of the different profile connection spaces
3) Comparison of the different profiles to the ISO-standard ISO 12641-1997
4) Comparison of Delta E and Delta E-94 differences between the ISO-standard and the different scanner targets
5) Lab comparison of the RGB and CMY color values from the digital test image towards the physically measured RGB and CMY values from the IT8-targets (A, B, C)
6) New test chart creation
7) Modification of the test chart’s output saturation and how this affects the gamut

5.2.4 Adapting the IT8.target for scanners
There are several vendors producing IT8-targets for scanner characterization. The targets follow a certain pattern based on ISO standardization values in LCH (ISO 12641-1997).

The scanner target consists of a total of 264 colors, as shown in Figure 40. The target design is a uniform mapping and is defined in detail in the ANSI standard IT8.7/2 for reflection material (ISO 12641-1997)

Figure 40: The scanner target consists of a total of 264 colors. The red frames show the standardized values.
Twelve separate hue angles are defined at three separate lightness levels. For each specific hue angle and luminance level, there are four different chroma values. The highest chroma value is defined as the maximum chroma which can be generated on a given medium with no change in the hue angle and lightness level. A further 84 patches provide additional tone scales which are not defined by any ISO-standard. Seven tone scales are defined for the colors cyan, magenta, yellow, red, green and blue (no ISO standard defined). Each tone scale is built-up in twelve steps starting from the lowest chroma value and keeping the hue angle stable. Each vendor has defined an optimal tone scale for their own specific output media.

The last three columns in the test chart are vendor-specific. Here the vendor manufacturing a target was allowed to add any feature they deemed worthwhile. Each vendor has chosen to use this area differently. Kodak has chosen the image of a model and several skin tone patches; Agfa and Fuji have both chosen to have patches of special colors in this area (McDowell, 2002).

A scanner profiling program makes it possible to characterize the color reproduction of a scanner and thus:

- to optimize color on input, and
- to synchronize the appearance of multiple scanners, so that a large production job can be divided among several scanners with no noticeable difference in color reproduction characteristics

(Adams II, Lind, 2001)

5.2.5 Result - adaptation of the scanner test chart

It is possible to produce a custom-made IT8 target and achieve a result similar to that obtained with the standard test charts on the market. The advantage of producing your own test chart is that it is possible to achieve a better match to the originals being scanned. In addition, customized color patches can be added for specific color values, as shown in Figure 41.
5.2.6 Conclusions

The color charts differ in color gamut when using the same settings. To more accurately capture an image with a certain color gamut, the scanner ought to be characterized with a similar or slightly larger color gamut so the image gamut falls within the ICC-profiles color space. Reference readings of the IT8 test charts need to be measured at fixed intervals in order to receive a more correct color gamut. To keep the color gamut of an image stable throughout the reproduction process, it is crucial to have a similar input profile size as the original color space and the profile connection space. This will keep the colors unaffected throughout the conversion stages.

The three major test chart producers (A, B, C) plus the new IT8-target differ from each other which will affect the color conversions from the scanner profiles to the profile connection space.

Figure 41: The customized IT.8 target for scanners made by Enoksson and Aviander.
5.3 Paper III, TAGA 2004, San Antonio, USA

“Image Reproduction Practices”

5.3.1 Introduction

Original images handled by the prepress departments are usually digital images in the RGB-mode (Red, Green, Blue). However, in order to print an image it must be converted into the printable base colors, CMYK (Cyan, Magenta, Yellow, Black). This color conversion is today done by ICC-profiles. The profiles contain information about separation, black start, black width, total ink coverage. GCR (Gray Component Replacement) and UCR (Under Color Removal) are the two main color separation techniques used to control the amounts of black, cyan, magenta and yellow needed to produce the different tones. Since black ink can replace equal amounts of cyan, magenta and yellow to produce a similar tone, UCR and GCR replace equal amounts of cyan, magenta and yellow in neutral tones. GCR also replaces some CMY colors in tertiary colors. These separation techniques can be optimized for different paper stocks in order to achieve a good tone distribution. The total amount of ink used in a printing process must normally be reduced in order to avoid printing problems such as slurring and quality problems such as lack of image detail.

5.3.2 Objectives

The purpose of this study was to investigate the level of knowledge concerning image separation and the use of ICC-profiles in the graphic arts industry in Sweden. This study relates to research area 1 of this thesis.

5.3.3 Method

The investigation has involved two separate studies over two different periods of time.

The first study was performed in 2000 when ICC-profiles were used by only a minority of Swedish printers. Color separation, at that time, was performed directly in image scanners or in imaging applications (i.e. Adobe Photoshop) using color look-up tables. A total of 120 companies, both printers with prepress departments and dedicated prepress houses, participated in the study. The companies are all located in Sweden, with an even geographical spread throughout the nation. The printers and prepress houses were also chosen on the basis of the size of the company, but only companies with two or more employees were included in the survey. Semi-structured interviews were conducted with prepress representatives, normally by telephone or
by e-mail. Ten company visits were made. A number of questions concerning the different separation techniques were asked in order to be able to assess the general level of competence.

The second study was performed in 2003. Eighty sheet-fed offset printers and thirty-four newspaper printers, evenly geographically spread over Sweden, participated in this study. Companies with only one employee were not included. As in the first study, semi-structured interviews were conducted with prepress representatives for each printer or prepress house either through a visit or by e-mail. A structured web questionnaire was also used. The questions asked concerned the use, creation and implementation of ICC-profiles. Approximately 50 percent of the printers/prepress houses participating in this study were also involved in the first study. In order to verify the findings and clarify the results, nine independent color consultants were contacted and interviewed.

5.3.4 Results and Conclusion
The studies indicated a serious problem in the graphic arts industry. The problem was related to both insufficient knowledge of color management and lack of communication. With regard to knowledge, there was a lack of competence and a shortage of literature and instructions which could help printers to better understand the technology. The communication problem was due to a lack of a common language, due mainly to the different backgrounds and experiences of the people involved. A knowledge of other people’s field of expertise is necessary to establish better communication between, for example, pre-press and printing personnel. The studies also show that there is a need for further education in the graphic arts industry.

The first study showed that:
- only a minority (20%) of the printers and prepress houses had a good knowledge of how their image conversion was performed
- more than 50 percent of the printers asked for dedicated technical training in their field
- there is a need for instructions and guidelines written in an understandable way
- the instructions must be written to be understandable by non-experts
- there is often poor internal communication within companies, especially between the press operators and the prepress staff working with imaging and the consultants
- there was a common hope that an ICC implementation would solve the major color reproduction difficulties
The second study showed that a majority (70%) of the commercial printers nationwide in Sweden are using ICC-profiles for color reproduction, particularly in the newspaper industry (83%). The majority of the participants in the survey felt that there was a lack of communication or non-existing communication in all process directions. There is normally no dedicated time for quality meetings. The newspapers have a better know-how than commercial printers concerning color management. Few companies set a strategy for their color management implementation and they therefore may not use the consultant in the right way. Terminology confusion is common in the graphic arts industry. The study shows that many pre-press staff members use the terms incorrectly or mix them up. The survey indicates that external consultants play an important role in the creation of ICC-profiles.

5.3.5 Comments
This lack of knowledge is not a feature only in Sweden. Other studies (Marin, 2004) have revealed that other countries have similar problems. Developing ICC-profiles is not necessarily an easy process. Based on the data collected (Marin, 2004), the following were the top five problems the respondents experienced in implementing color management software:

**Top five Problems with Profiling**

1) Device calibration
2) Misunderstood profiling set-up options
3) Lack of understanding of the profiling process
4) Inappropriate test target
5) Inappropriate profiling software
   (Marin, 2004)

A company must achieve quality by understanding and improving systems and by preventing problems (Apfelberg H, Apfelberg M, 1999).

It was shown that there was a great need to further educate personnel in printing. Training in elementary color theory and explaining the commonly used types of software are of great importance.
5.4 Paper IV, TAGA 2005, Toronto, Canada,
“A Digital Test Form for ICC-profiles”

5.4.1 Introduction
Studies (see Paper III) performed during the years 2000 and 2003 revealed that the graphic arts industry has a knowledge problem. The problem concerns both an insufficient knowledge of color management and a lack of communication. The people within the graphic arts industry complain about the shortage of literature and instructions which could help printers to better understand the technology.

An increasing number of graphic arts companies are using ICC-based color reproduction. The companies either create their own printer profiles, or hire consultants to create the profile. A survey described in Paper III, showed that 70 per cent of the Swedish sheet-fed offset printers need the assistance of a consultant in the ICC-profile creation process. The choice of software tool plus the software-specific separation settings are also made by consultants. Printers/prepress houses have difficulties in adjusting specific parameter settings in the profile, due to insufficient color management skills. The survey proved that there is a need for pedagogic tools in order for the user to better understand their own process. All graphic terms and techniques set high demands on the users at printers and prepress departments.

5.4.2 Objective
The purpose of this study was to create a digital test form using the most common color imaging software on the market - Adobe Photoshop – in order to promote the practical understanding of profiles and their use.
This study relates to research area 2 of this thesis.

5.4.3 Method
The project focus was to find a suitable mix of images and test areas in order to illustrate the differences in color spaces, gamut colors, color renderings and separations in a simple and pedagogic way. A number of applications have been tested for the creation of the test form; Adobe Illustrator 10,0 and Adobe Photoshop 7.0 were the final choice. Eight graphic consultants, three printers and their customers have been acting as a test panel in order to evaluate the test form created.

The test form is intended for use in Adobe Photoshop, since this application is most widely used for color imaging in Sweden.
5.4.4 Result
The created test form can provide information to the user about many settings in the profile. The test form helps to show the differences between the settings already in the RGB color mode and to avoid misunderstandings after printing. The layout of the test form facilitates practical understanding by showing the result of a color conversion from RGB to CMYK using a profile.

The digital test form gives information about:
- ICC-profiles in MacOS and Windows
- Different color gamuts
- RGB Gray balance
- Rendering intents
- Gamut warning
- Separation
- CMYK gray balance
- Chroma shift
- Gamut mapping
- Skin tones
- Total Ink Coverage

The images are pedagogically developed in order to facilitate understanding and the ability to analyze changes in the settings of a profile, Figure 42. The digital test form was complemented with lightness circles describing the LAB-color space in five lightness levels, Figure 43.

5.4.5 Conclusion
It is possible to create a tool which explains in pedagogical way the different graphic terms and which facilitates the understanding for the users.

5.4.6 Comments
Printing personnel are often short of time, and the maintenance of production goes before all testing. The personnel are, in other words, fully concentrated on handling production demands, leaving little time for personal initiative. To read manuals and thereby learn more about a certain software has been shown to be a poor alternative, as manuals are often written in a difficult way, and often in a foreign language. Exercises that are based on a “step-by-step” approach often help the user to solve a lesser problem, but without granting the user any deeper knowledge. What the graphic arts
industry needs is a tool which helps the users to help themselves. By using such a tool, the user can test the different settings and applications included in the software, and later apply this newly gained knowledge to his own productions, his own color proofing system, printing machine, etc. Furthermore, graphical definitions should preferably be exemplified by pictures, facilitating the understanding of definitions, explanations and any differences.

Figure 42: The digital test form for the evaluation of ICC-profiles (Enoksson, 2004).
Figure 43: The lightness circles in five levels for evaluation. To better understand how the settings affect the result, the user can see the changes in two directions - the vertical direction (the matrix on the digital test form, see Figure 39) and the horizontal direction (the lightness circles on the digital test form).
5.5 **Paper V**, VII. Polygraficky seminar, 2005, Pardubice, Czech Republic

“*Demand specifications for controlled color reproduction*”

### 5.5.1 Introduction

An increasing number of printers are using ICC-based color reproduction, to improve repeatability and predictability in the color reproduction process. Many printers use external color consultants for their color management integration. The information they give to the printers concerning the specific parameters used in the profile creation varies.

In order to be able to have a constructive discussion between all participants in the color reproduction chain, it is vital that each reproduction step be fully understood, optimized, and controlled. General reproduction guidelines can be a useful aid in communication to optimize each step in the color reproduction process.

### 5.5.2 Objective

The purpose of this paper was to define specifications to simplify and improve color communication not only between consultants and printers but also internally between the prepress and pressroom departments within the company.

This study relates to research area 1 of this thesis.

### 5.5.3 Method

Definition of the specifications, called “communication list” in the paper, is based on visits to printing companies and a survey. Thirty lithographic offset printers in Sweden were contacted during 2004 by e-mail, telephone or personal visits to clarify their internal technical specifications relating to color management. Visits were made to fifteen of these companies. The survey questions were prepared to enable the demand for specifications between printing companies and external consultants, as well as internally between the prepress and press departments, to be analysed. This survey was complemented with visits to another twenty printing companies and two paper mills. The interviews in this part of the survey were semi-structured. Five color consultants have been interviewed after the surveys to verify the result and in order to obtain a general impression of their points of view. The questions in these interviews were also semi-structured.
5.5.4 Result
A list describing the specifications one should understand when building an ICC-workflow for print reproduction has been constructed. An understanding of these specifications will facilitate internal communication within a printing company, and also between printing companies and external consultants creating ICC-systems.

The survey showed that none of the printing companies had a well-prepared list of specifications for the construction of ICC-profiles other than “functioning profiles” and that people relied on each others´ competence. The survey also showed a great need for a “how-to check list” for profile creation, which would be helpful to facilitate communication internally and externally.

The discussions with consultants in the graphic arts industry tended to bring up “process thinking” more and more often. According to the consultants, we must learn to see the graphic printing business as a process industry. Each process (i.e. prepress, press, postpress) needs to be linked to others. In order to link the processes, we must understand the specifications for each process, what to input and what to output and who is responsible for the process. All processes used must be defined and a process representative must be defined and given responsibility. During training sessions for printing personnel, prepress personnel should also attend (and vice versa) so that the knowledge of each others´ disciplines increases, and communication is made easier. An improved communication will give a better process understanding and thereby a better production quality. Thus communication is the key word, both orally and written. We have to learn to communicate in a way which is comprehensible to non-experts. This will strengthen a company´s production process as a better communication gives better quality – both internally within the company and to the customers. Education of those involved is needed to achieve better communication.

5.5.4.1. The color communication list presented five parts:

1) General demands/specifications
This part of the list contains objectives, implementation and specifications. Before a profile-based production can be considered, comprehensive objectives need to be set. The purpose of the process change must be explained to the personnel directly involved in the production process. General information about profile implementation needs to be given. To avoid common misunderstandings and improve internal communication, written process instructions should be followed. Each process should be defined and described, with regard to responsibility and demands.
2) Test form specifications
This part describes responsibility distribution according to the creation
and content of the test form.

3) RIP (Raster Image Processor) specifications
This part of the communication list describes initial demands – lineariza-
tion and setting of the RIP.

4) Output profile specifications
This part describes responsibility distribution according to settings in the
profile.

5) Printing specifications
This part describes initial demands, general facts and standard demands.

It is not a complicated task to produce profiles if the specifications for the separate
processes are well defined. For each process, there must be at least one person in
charge. There must be pre-established control measurements for the process with
given tolerances and instructions regarding the frequency of measurements. Control
data must be saved over a period of time in order to simplify fault-finding in the event
of non-confirmative results. Each step in a color management set-up must be docu-
mented so that a later profiling update can be established with the same set-up. What
specifications are crucial for the internal communication within a printing company?
If the printing company uses a color consultant for the print profile creation, for
which process steps is the consultant responsible and which steps are the printers’ re-
ponsibility? By confronting these issues beforehand, many mistakes can be avoided,
simply by using a more direct communication.

The communication list deals with specification demands which are of importance in
the development of profiles and different responsibility distributions in the develop-
ment of these profiles. Two scenarios are described: the first situation is when the
printing company creates its own profiles without the involvement of an external con-
sultants, and the second scenario describes the situation when the printing company
needs external help to create the profiles.
5.5.5 Conclusion - the communication list

Introducing a profile-based process flow involves planned work with clearly detailed goals. It means a thoroughly worked out plan with a clear goal from the start. All processes used must be defined and a process representative must be appointed and given responsibility. Effective communication between the printing and prepress departments is the goal. During training sessions for printing personnel, prepress personnel should also attend (and vice versa) to increase the understanding of each other’s disciplines and facilitate communication. It is important to point out that the printer’s role has changed. Apart from having the printer’s skills, a more active part must be taken in the prepress work. An improved communication will give a better process understanding and thereby a better production quality. When constructing a profile, the process owners involved must participate. One person should lead the process, preferably from the printing press area, and there must be a documented information interchange between all involved parties.

“It is important to know that color management is more than just making or using ICC-profiles. Color management requires calibration, process control, collecting good measurement data, understanding application and drive settings, and above all, bringing all these together into a coherent workflow” (Fraser, 2003).

Based on a survey (Marin, 2004), these points should be kept in mind to help achieve success when implementing color management:

- process controls should be implemented in your organization before trying to color manage the workflow
- the color management process requires training
- know that color management is a process
- give it time

External customer demands for quality are growing continuously. Therefore, a continuous improvement in the quality of goods and services produced by the company is vital. Improving continuously is an important element in a successful quality strategy. The costs for poor quality in the Swedish industry are often estimated to be 10-30% of the sales (Bergman, Klefsjö, 2003). As an example of the consequences - see Figure 44.
This happens if we accept that 99% accuracy is sufficient:

• Nine words are incorrectly spelled on each page of your newspaper.
• Almost four times per year you will not get your newspaper.
• You should be without electricity, water or heating about 15 minutes each day.
• At least 8500 prescriptions would be incorrectly prepared each year.
• About 23700 transfers should be made to the wrong bank account each day.
• Drinking water in the water pipe system would unusable about 1 hour per month.

Figure 44: An example of consequences in “Kvalitetsbristkostnader” (Lack of Quality Costs) (Hedman, Lindvall, 1993)
5.6 Paper VI, TAGA 2006, Vancouver, Canada

“Compensation by Black - a new separation?”

5.6.1 Introduction
There are basically two types of separation: UCR and GCR. These separations can reduce or remove a gray component made up of yellow, magenta and cyan inks and replace it with a suitable amount of black ink. These separations are still a major cause of confusion, as very few users actually know what these separations mean and how the settings affect the final result.

5.6.2 Objective
The aim of this paper was to examine the differences between UCR (Under Color Removal) and GCR (Gray Component Replacement). This study relates to research area 2 of this thesis.

5.6.3 Method
This study explains the differences between GCR (Gray Component Replacement) and UCR (Under Color Removal) by testing these separation functions in three applications: Adobe Photoshop CS (an image editing application), Gretag Macbeth’s Profile Maker 5.0 (profile maker), and Heidelberg’s Print Open 4.0.5 (profile maker). The literature relating to the different types of separation was reviewed. An Internet search was also made to check what a prepress employee would find if he or she was to search for a definition of one of these types of separation.

5.6.4 Background - UCR and GCR
In an article in the RIT T&E Center Bulletin (September-October 1984, vol.12, no 6) written by Franz Sigg and Patty Cost, it was stated: “The term UCR would therefore no longer be used, because its function would be fully covered by GCR”. Twenty-two years have passed since this article was written by Sigg and Cost, and nothing has happened since then. The situation has not been made easier for users, and no attempt has been made to increase their understanding. Why not?

The original meaning of UCR was lost about 25 years ago when the third generation of electronic scanners targeted the lithographic printing industry. The first theoretical principles of UCR were developed by Yule, and his theories were first applied to conventional separations, and later to the first electronic scanner, the Time-Life/PDI scanner in the early 1950s, Figure 45. The limitation of conventional masking
methods in applying UCR to neutral tones only later became the standard opinion about UCR. In a later paper, Yule expressed his regrets that the initial scope of UCR had been perceived to be limited to neutral tones. He then went on to say that this had become the “standard opinion” in the industry, and he therefore introduced the concept of Extended UCR.

Later, Extended UCR became known as GCR and inventive marketing from the leading electronic scanner manufacturers in the early 1980s has contributed to the confusion. “New” functionality was marketed in the beginning of the 1980s, and new acronyms were coined: PCR, CCR, ICR.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCR (Polychromatic Color Reduction)</td>
<td>Crosfield</td>
</tr>
<tr>
<td>CCR (Complimentary Color Reduction)</td>
<td>Hell</td>
</tr>
<tr>
<td>ICR (Integrated Color Removal)</td>
<td>Dai Nippon Screen</td>
</tr>
</tbody>
</table>

Figure 45: The figure (Carlsson, 1967) shows the Time-Life PDI scanner from the 1950s. The first application of UCR in electronic scanning was used (Yule 1940). Size = XXXL and very heavy. Same size exposure – transparency to separated con-tone negatives. Capacity < 3-4 times the conventional methods. This scanner was used for Time and Life publications printed in wet-in-wet (trapping problems).
5.6.5 Results
The investigation of both recent literature (1989 - 2004) and manuals from frequently used software shows that two different types of separation, GCR and UCR are described. The difference is that UCR works only in the neutral dark areas and that GCR seems to work over the entire tone range (where the three CMY-colors are present).

The tests in the three applications (Adobe Photoshop CS, Profile Maker 5.0 and Print Open 4.0.5) generated similar results for UCR and for the lowest level of GCR. It is difficult to draw a border between these two separation types. UCR is really a “light type” of GCR or “GCR level 1”.

5.6.6 Conclusion
The study has led to two alternative proposals:

1) Discard the term UCR and use only GCR, as it really only concerns gray component replacement. This would make it easier for people in the business to focus on the process itself instead of trying to understand the difference between the two types of separations, a difference which cannot be seen visually.

2) Discard both terms and introduce a new term: CB (Compensation by Black). The software should make it possible to choose how much black will be used and where it will replace a combination of the CMY process colors. In addition, a single term would make the user more aware of the problems of separation and of how separation will affect the print result.

The suggestions imply an extensive review of accepted terms and abbreviations within the graphic arts industry in order to achieve a uniform scientific meaning and definition. Thus, it is strongly recommended that the term, CB (Compensation by Black) should be implemented.
5.7 Paper VII, TAGA 2004, San Antonio, USA

“Using Gray-Balance Control in Press Calibration for Robust ICC Color Management in Sheet-Fed Offset”

5.7.1 Introduction

When ICC-profiles were first used, there was a tendency to create profiles for many different combinations of printing presses and papers. It has even been stated that a new ICC profile needs to be made for each new paper delivery. Naturally, this would be overwhelmingly time-consuming and expensive.

Today, it is more common to reduce the number of ICC-profiles, and most parties benefit from fewer profiles. How many profiles are needed, and which way of working is then required? The idea behind this paper was that the fewer the number of ICC-profiles for sheet-fed offset, the better. To make this possible, printing presses must be calibrated. Calibration was accomplished by combining target density levels and gray-balance control.

Cold-set printers often use gray-balance fields for the adjustment and control of ink quantity during print runs. This method helps the printer to significantly reduce unwanted color cast in the printed product. A common technique to control the amount of ink in sheet-fed offset is to decide upon target tone-value increase (TVI/dot gain) or density levels, with the intention to print the best subjective quality, even though the same quality cannot always be attained in every print run. Today, a predictable and equal quality is generally desirable, and calibration and standardization are therefore more in focus. Since there is no standardized way to calibrate a sheet-fed offset press, the possibility of producing an equal print quality in different print runs and printing presses is limited.

Gray-balance control is one way to calibrate a printing press. The press will then always be set to print one standardized combination of CMY halftones in the same way. Hopefully, this will create a similarity between print runs, presses and to some extent paper grades, which provide the foundation for robust ICC-profiles.
5.7.2 Objective
The objective of this study was to find a way of calibrating a sheet-fed offset press, so that the color reproduction on different papers will be similar enough to permit the use of fewer of ICC-profiles. This study relates to research area 3 of this thesis.

5.7.3 Method
The use of gray-balance control in sheet-fed offset was explored and the stability of ICC-profiles was assessed in gray-balance-controlled print runs. The inking levels in the press were set to print given CMY combinations neutral on five wood-free coated papers (ISO12467-2). If the press is always set to print this standardized CMY combinations so that the result looks the same, it should be possible to use the same ICC-profile in all the print runs.

ICC-profiles were created for each of the five papers and they were then used for all of the papers, in gray-balance-controlled print runs. To compare the different combinations of ICC-profiles and papers, CIE LAB images and test charts were converted to CMYK, printed and then measured or evaluated visually. The deviation in ΔE-units was used as a measure of the stability.

5.7.4 Result
It was found that it was possible to print without a color cast, and still keep print contrast, density, dot gain and CIELAB values for the secondary colors at an acceptable level. Prints on different coated papers were compared, to investigate the similarities between these samples, when using this method and ICC profiles. The study showed that a single ICC profile can give similar print quality on different papers.

5.7.5 Conclusions
It was evident that gray-balance control can be utilized in sheet-fed offset. The printable color gamuts and the neutrality in the three-color gray were sufficiently similar between papers and print runs to enable good gray-balance control to be achieved. However, in sheet-fed offset gray-balance control should be used in combination with target density levels; the “gray-balanced” targets have to be controlled and, if necessary, adjusted in each print run.
The ICC-profiles created from the gray-balanced print run were found to be quite robust. Combining the results from the objective and subjective evaluations, the following three conclusions could be drawn:

- the printed results were similar when the gloss or dull (silk) ICC-profile was used on the classic matte, dull (silk) and gloss papers

- the printed results were similar when the classic matte ICC-profile was used on the classic matte, matte and dull (silk) papers

- if an average $\Delta E^*$ $\leq 3$ and the worst $\Delta E \leq 5$ are considered to be good enough, one ICC-profile for coated (fine) paper ought to be sufficient, preferably created for a glossy paper
5.8 Paper VIII, TAGA 2008, San Francisco, USA

“Gray Balance Control in Sheet-Fed Offset Printing”

5.8.1 Introduction
Gray balance is critical for good color reproduction, and is a function of ink hue, ink film thickness and the percentage of dot area being printed. It is also affected by color sequence, ink trapping, press characteristics and dot gain. Proper gray balance ensures that a tone of appropriate cyan, magenta and yellow tint values is visually perceived as neutral gray (Flexographic Technical association, 1984).

The human eye is most sensitive to small changes in the color balance of neutrals and colors close to the neutral axis. As color becomes less saturated and closer to the neutral gray axis, the eye becomes more sensitive to even small changes in chroma (NAA, 2000). Due to the fact that as “the eyes are sensitive in detecting color differences within the gray zone, they can serve as a visual metering device” (ECI/bvdm, 2007).

Newspaper printing can be controlled by gray balance, a procedure which is widespread among newspaper printers in Sweden. In sheet-fed offset today, there is no fast and easy way to control a sheet-fed offset-press during production without using advanced time-consuming online-systems. At least in Sweden, the commercial offset printers have no special organization which could help implement such a method.

5.8.2 Objective
The first objective of this study has been to evaluate the subjective quality experience (and objectively measurable factors) of print, where the quality control has been carried out with gray balance in sheet-fed offset. The second purpose was to implement gray balance as a quality control tool for the printers in sheet-fed offset press. This study relates to research area 3 of this thesis.

5.8.3 Method
This study about printing by gray balance in sheet offset is based on objective evaluation (measuring of density, spectral measuring, creation and comparison of print profiles) and subjective evaluation, paired comparison, (Torgerson, 1958)). The study started with two test printings (called Printing 1 and Printing 2) to check the printing parameters in the Heidelberg Speedmaster-74 (Spektra screening, a hybrid half-tone screening technology). The paper used in this study was a glossy paper 130g/m². The
print test form contained, in addition to different control strips, a color image and a neutral image which was printed by CMY, see Figure 46.

The print tests, called Printing 3 (i.e. controlling by density) and Printing 4 (i.e. controlling by gray balance) were performed in two ways on the same day and Printing 5 (i.e. printing of the images separated by profiles based on Printing 3 and 4)) was printed two months later.

a) the print which was controlled by density
   (called Printing 3 in this study)

100 sheets among the accepted prints were randomly selected and measured (Techkon spectrophotometer, measuring of the ΔE*). Ten of these 100 sheets which had the best agreement with the ISO-standard 12647-2:2004/Amd.1:2007(E), were also measured by EyeOne (X-Rite). The subjective evaluation of the printed images was done by paired comparison. Print ICC-profiles based on the best sheets were created.

b) the print which was controlled only by gray balance
   (called Printing 4 in this study)

The sheets which were needed by the printer to obtain an acceptable gray balance were collected and measured in order to check human eyes. 100
sheets from the accepted prints were randomly selected and measured (Techkon spectrophotometer, measuring of the ΔE). Ten of these 100 sheets, which had the best agreement with the ISO-standard 12647-2:2004/Amd.1:2007(E), were also measured by EyeOne (X-Rite). The subjective evaluation of the printed images was done by paired comparison. Print ICC-profiles based on the best sheets were created.

The subjective evaluation was done using ten people, students and teachers at a college Graphic Arts Technology department. These people were selected because of their depth of knowledge regarding graphic arts terminology, for example color cast and gray balance. The test people could see and compare two images at a time-paired comparison. The evaluation was done as follows: the image which was judged as the best was given 1 point (100 points maximum) and the other one got 0 points. Based on the subjective evaluation, mean values and standard deviations were calculated. The test people were instructed to judge the image quality regarding color cast and best gray balance. Prior to the paired comparison, every person was checked (on a calibrated computer screen) for color blindness using the Ishihara Test for Color Blindness (Toledo-bend, 2007). All ten test people passed this test. The images from both prints, Printing 3 and 4 (i.e density versus gray balance) were also compared to each other.

c) the print which contains the images separated by different profiles
(called Printing 5 in this study)

The images (the color image and the neutral image) were separated using the new ICC-profiles (based on Printing 3 and 4) and printed in a new run. The results were evaluated subjectively and also compared with the same image separated by standardized ICC-profile, ISOcoated_v2_300_eci.icc. On the print test form, there were also different patches of gray in order to allow subjective and objective evaluation of the differences in the patches.

Implementation was carried out after the tests at the Company A, which has 47 employees of whom six were involved in the tests and the implementation. The desires from the company management were to make ready-time shorter and to make a faster acceptable first sheet with preserved quality. Implementation started with education and semi-structured interviews with the printers (four printers).
5.8.4. Result
The results of this study are presented in six parts:

1) Test Printing 3 (P3), controlling by density, evaluation and measuring of the sheets
   
   **Result:** Ten sheets (A,B, C, D, E, F, G, H, K, J) in Printing 3 have been evaluated. The subjective evaluation identified the three best sheets A, K, I, as well as sheet G which received the lowest number of points in the paired comparison. These sheets were selected for the following tests. (For more information see the Paper VIII).

2) Test Printing 4 (P4,) controlling by gray balance
   evaluation and measuring of the sheets
   
   **Result:** Printing 4 was checked only by gray balance evaluation. The printer needed 26 sheets to finish the check. Ten sheets in Printing 4 have been evaluated. The subjective evaluation identified the three best sheets, H, I, J. Sheet B received the lowest number of points in the paired comparison. The printer had the same problem (density in the yellow ink) during the printing by gray balance as during Printing 3. Similar to the other printing tests, the density varied across the sheets. After sheet 26, the following sheets had ΔE ≈ 5. In spite of this fact, sheet 27 (i.e. sheet P4 H) received the lowest number of points for the neutral image in the subjective evaluation and the next lowest number of points for the color image. However, three out of ten people have judged sheet 27 as the best. The last sheet which was checked by the printer, sheet 26, received the highest number of points. The profiles based on the sheets are almost identical, except sheet 27, which has a bigger gamut in the yellow area.

3) Evaluation and comparison of printing by density and printing by gray balance (P3 versus P4)
   
   **Result:** The subjective evaluation showed that all sheets from Printing 3, except sheet G, received a higher number of points in the paired comparison than sheets from Printing 4 for the neutral image. All sheets from Printing 4 got a higher number of points for the color image.
4) Creation of the profiles based on printing by density and on printing by gray balance

**Result:** The profiles from the best sheets from Printing 3 (sheets A, I) and Printing 4 (sheets H, I, J) have been created and compared with each other and with ISOcoated_v2_300_eci.icc. (www.eci.org), see Figure 47. The profile based on Printing 4 (controlling by gray balance) is more similar in size to ISOcoated_v2_300_eci.icc than the profile based on Printing 3.

The profile which represented Printing 3 (controlling by density) at a new printing (called Printing 5) was the average from sheets P3 A and P3 I. The profile which represented Printing 4 (controlling by gray balance) was the average from sheets P4 I and P4 J. The profile based on Printing 4 and the ISO-profile have similar sizes. The profile based on Printing 3 has a smaller size in the yellow area. The images were separated with the new profiles (based on Printing 3 and Printing 4) and printed again, Printing 5.

![Figure 47: The comparison between the profiles: the red profile is Printing 4, the yellow profile is Printing 3 and the green profile is ISOcoated_v2_300_eci.icc profile.](image)

5) The Printing (Printing number 5) of the images which were separated by profiles based on printing by density and by gray balance

**Result:** A new test form and a new control strip based on checking density and gray balance were created for Printing 5, see Figure 48. The test form contains the neutral and the color images separated with the ISOcoated_v2_300_eci.icc (www.eci.org) and the profiles based on Printing 3 and Printing 4. The new control strip is based on the Heidelberg strip used
in the printing company. The printer had the possibility to see and visually check the gray balance across the sheet but he also had the possibility to measure the density.

![Figure 48: The new test form for Printing 5, the red circle shows the hidden words inside the patches.](image)

A subjective comparison and evaluation was done between the printed images (the neutral and the color images). The first evaluation was done between the printed images separated with a profile based on Printing 3 and Printing 4. In a second evaluation, the test people had to decide which of the images were more similar to the image that was separated using ISOcoated_v2_300_eci.icc:

The result showed that all test people preferred both the color image and the neutral image which were separated with profile based on checking by gray balance (Printing 4) more than the images separated with the profile based on printing by controlling density,(Printing3) see the results in Figure 49. However, all test people said that both images (neutral and color) from Printing 4 were most similar to the image, which were separated by ISOcoated_v2_300_eci.icc.

<table>
<thead>
<tr>
<th>Neutral image</th>
<th>Color image</th>
<th>Similarity with ISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printing 4 = 10 points</td>
<td>Printing 4 = 10 points</td>
<td>Printing 4 = 10 points</td>
</tr>
<tr>
<td>Printing 3 = 0 points</td>
<td>Printing 3 = 0 points</td>
<td>Printing 3 = 0 points</td>
</tr>
</tbody>
</table>

![Figure 49: The result from the subjective evaluation. The Printing 4 is the “winner”.](image)
6) Implementation of the gray balance as a tool for the printers for quality control in sheet-fed offset press

Result: The implementation at Company A started directly after the tests, education of the printers, and interviews with the printers. Interviews with the printers confirmed that the printers accepted and understood the point of gray balance and the new working procedure. The new strip based on checking density and gray balance was used for further printing at Company A. Basic conditions for the usage of gray balance were more efficient measurements, preserved or better quality, and easier communication.

• interviews with the printers (four in total) confirmed that the printers accepted and understood the point of gray balance and the new working procedure
• interviews with the printers showed agreement with each other
• fewer time-consuming measurements due to fewer patches, i.e. shorter make-ready time
• preserved good quality

5.8.5 Conclusion
The study shows that a gray balance control strip is a very good instrument. The results show that the sheet-fed offset process can be controlled by gray balance in the same way as the newspaper process. The images which were separated with the ICC-profile “based on the eye” (Printing 4) showed in the subjective evaluation better agreement with the ISOcoated_v2_300_eci.icc.

This study about gray balance has shown that:
1) The gray balance can be used as a control parameter for control of quality in sheet-fed offset. This assumes of course that the printer has proper visual color vision.

2) A faster make-ready time and more reliable print quality (fewer variations during production) can be achieved.

3) The printer and the customer can be given access to a tool which facilitates communication, generates fewer misunderstandings, leads to less product returns, and thus can create savings in time and material.
5.8.5 Comments

The new strip which is based on gray balance is in use today at the printing house where it was tested. However today the strip also contains the patches with cyan, magenta and yellow but the number of patches has been decreased by 50% to make room for gray balance patches. The results of this study showed that the effectiveness has increased due to the fact that the number of measurements on the control-strip has decreased by 50%. It is easier for the printer to visually detect deviations without time-consuming measurements and without wasting paper, especially if the press is running during evaluations and adjustments.
6 Conclusions and discussion

The purpose of this thesis was to investigate how new tools and tools adapted to a specific production set-up can be used to raise awareness regarding the quality and workflow of images and image processing for sheet-fed offset within the graphic industry.

The work was divided into the following three study areas with several sub-studies:

6.1 The first objective - Identification of actual knowledge levels

The first research goal of the thesis was to identify knowledge levels regarding color separation of images and demand specifications within printing houses, in order to know which measures need to be taken, e.g. what tools are required to meet the graphics industry’s needs. To identify these actual knowledge levels, three surveys were performed:

6.1.1 Case studies - the surveys

Two surveys were performed (during the years 2000-2004) at printing companies in Sweden to assess the knowledge level, and the level of understanding of image separation, and the use of ICC-profiles in the graphic arts industry. The surveys indicate a serious problem in the graphic arts industry, involving both an insufficient understanding of color management and a lack of communication. There is a lack of competence and a shortage of literature and instructions which could help printers to better understand the technology, and there is no common technical language. There is clearly a need for further education in the graphic arts industry.

The following actions are suggested:

a) further education of personnel
b) the development of material which explains definitions in a simple and pedagogic way
c) a clearer responsibility distribution in the organization
d) a simplification of definitions

Today, printers play a more central role in the process where the demands for understanding are increasing. The printers must not only be the masters of the printing process, they also have to take a more active role in the prepress process. Color separation settings (for example color separation, total ink coverage, black width) performed in profiling applications often affect the printers’ work without their knowledge. Printers must be offered greater possibilities to change and discuss the settings
in software which create the ICC-profiles used for printing. Not only do printers need further education, other groups in the graphic production chain, for example pre-press personnel, need further education as well. Software used at printing companies is under constant development; new versions are becoming available more and more rapidly. As a consequence, the personnel need more time to study the new functions.

There is a need for instructions and guidelines written in an understandable way. Reading manuals can be quite a difficult task, so these instructions must be written suitable for non-experts so that everyone can fully understand the instructions and guidelines.

6.1.2 Demands specifications for controlled color reproduction
The purpose of this study was to define specifications to simplify and improve color communication concerning color separation not only between consultants and printers but also internally between the prepress and pressroom departments within the various companies.

A third survey was performed in 2004 and focused on demand specifications for controlled color reproduction. The result showed that communication between different departments of a printing facility must be improved. The pre-press department and printers must co-operate in the development of ICC-profiles. If external help is used, extensive documentation should be provided. A communication list based on the author’s study has been created, listing the important demands for specifications one should understand when building an ICC-workflow for print reproduction. These demands for specifications (a communication list) can facilitate not only the internal communication within a printing company, but also the interaction between printing companies and external consultants building ICC-systems.

6.2 The second objective - novel tools and novel understanding
The second objective of this thesis is to investigate whether novel tools and new terminology can help to increase the knowledge level regarding color management:

6.2.1 Pedagogical tool
A pedagogical tool was developed in order to assist in making color management understandable for users, and thereby optimize printing. For this purpose, digital test forms have been developed. These test forms, together with descriptive material, will facilitate the understanding of color management issues. Definitions within the field of color separations have been examined, and changes have been suggested.
There is no short cut to knowledge. One way to gain knowledge is to test how different settings and functions work. Practical use tends to grant a greater understanding than mere reading. The goal of the developed test form is improving the practical understanding of ICC-profiles and their use. The test form can help to point out the differences between the settings and different functions already in the RGB color mode and thereby avoid misunderstandings and disappointments after printing. The layout of the test form facilitates a practical understanding by showing the result of a color conversion from RGB to CMYK using a profile.

A new toolkit for evaluation of ICC-profiles was created, Figure 50. The goal of this educational kit was to facilitate and exemplify practical understanding of profiles and their use for users. The working material in the educational kit consists of five parts:

1) **Basic color theory**
   To be able to work with ICC-profiles, a basic knowledge of color theory is needed. In this kit one can find the basic theory one needs before starting to work with the profiles.

2) **A digital test form for ICC-profiles - testing of ICC-profiles in Adobe Photoshop**
   This educational kit provides the user with simple descriptions of different graphical definitions and settings which the user can also test for himself. The definitions are described in a simple manner, often with screen dumps from the software. In order to fully understand how different settings affect the final result, the user must test them.

Figure 50: The educational kit for evaluation of ICC-profiles, (Enoksson, 2005)
3) File for analyzing the results
The user can also print the actual test form, type in the measured values and interpret them on the Excel file. This file contains tables and diagrams, which can help the user analyze results (in the form of a diagram).

4) Testing of settings in profile making software PrintOpen and ProfileMaker
In the kit, the user will also find ISO-profiles (ECI-Offset 2004) and profiles made in PrintOpen and ProfilMaker. These profiles have been created using different settings (e.g. different kinds of separation, black width, black start, gamut mapping, etc). These profiles are created using the settings that the user can test himself using the included test forms.

5) Recommendations for additional reading
The user of the educational kit will find some useful links and books for additional reading.

The user can convert the digital test forms to the CMYK color mode and analyze the changes in the test forms. For a better understanding of the settings, the user can duplicate the digital test forms and convert them in different ways. The user can compare the results and see the changes in a pedagogic way because of the composition of the test form. To see, for example, how the black ink works in an image (the different settings for UCR (Under Color Removal), GCR (Gray Component Replacement, black start and black width), the user can study the black channel (in Adobe Photoshop) after the conversion. To better understand how the settings affect the result, the user can see the changes in two directions - the vertical direction (the matrix on the digital test form) and the horizontal direction (the lightness circles on the digital test form, Figure 41, page 76). The different settings for color conversions are described in the educational kit (Enoksson, 2005).

This tool has received international attention for its educational performance. After presenting the tool at the TAGA-conference, the author was invited to the ICC meeting in London. Subsequently, the author was granted an honorary membership, and a link to this tool was added to the ICC website.
6.2.2 New and easier terminology
Terms are often described differently in the literature and on the Internet. Examples of this are the techniques used to separate images - UCR (Under Color Removal) and GCR (Gray Component Replacement). These different terms and explanations are confusing for the graphic arts industry. Tests made using the currently available software (Adobe Photoshop - image processing, ProfileMaker - profile creation, PrintO- pen - profile creation) have shown that there is no greater difference between UCR and GCR. UCR has been shown to be a “GCR light”, as was suggested already in 1984 (Sigg, Cost, 1984): “The term UCR would therefore no longer be used, because its function would be fully covered by GCR”. The present work emphasizes that this 22 year old suggestion is still valid. It is important to make it easier for users to understand the technique in a simpler way. Therefore, a new term has been proposed - CB (Compensation by Black). This new single term would make the user more aware of the problems of separation and of how separation affects the print result.

6.3 The third objective - the adaptation of the control tools
The objective was to investigate whether process specific adaptation of key color control tools can improve quality levels:

The developed tools were adjusted to:
- a scanner test chart
- a printing test chart to image category
- printing in sheet-fed offset with a new strip using gray balance

6.3.1 Adaptation of the scanner test chart
In order to render an image in an optimal way, one can adjust the printing settings by deciding which area of the image contains the most important information. This information can be adjusted in various ways – for instance by choosing the gamma curve during scanning, or by adjusting an IT.8 test chart for scanners or for print. These adjustments to the IT.8 test charts generated good print results. The adaptation of an IT.8 test target for scanners made it possible to adapt the production. The advantage of producing a tailor-made test chart is that it makes it possible to achieve a better match to the originals being scanned. Customized color patches can be added for specific color values and this improves the color rendering. This thesis suggests that it is possible to produce a custom-made IT8 target and achieve a result at least similar to or even better than with the standard test charts on the market.
Conclusions and discussion

6.3.2 Adaptation of the printing test chart
Adapting the end of the process chain, the printing, makes it possible to give priority to certain areas in an image. This thesis has shown that it is possible to adapt the test chart for printing.

A low-key image separated by the image-adapted test chart showed more detail in the dark areas than a low-key image separated by the standard test chart, in the prints on coated paper. Coated paper has a smooth surface onto which it is easier to transfer the dots. On coated paper, the printed halftone dot has an even edge, whereas an uncoated paper gives an uneven dot shape. Uncoated paper gives more dot gain* than coated paper. Dot gain is not in itself a problem, but if uncontrolled it results in a deterioration of quality. The surface and the structure of the paper are sources of an (apparent) dot gain (Hansson, Aviander, 2006).

Due partly to dot gain it is difficult to achieve the same high quality on uncoated paper as on coated paper. The detail in the dark areas of the image has a tendency to disappear. An image adaptation of the test chart printed on uncoated paper may give even more detail in the dark areas.

An adjustment only to low-key images is sufficient, as even normal-key images then show a better fidelity to the original images. High-key images did not show any difference between the different IT.8 test charts, and no distinctions among them could be observed in the prints.

This research work has undertaken the task of adapting the IT.8 test chart to a special image category which is unique. The ideas and methods concerning IT.8 test charts adapted for printing are the subject of a patent, where a Swedish patent has been already granted (Enoksson, 2004). No similar work has been found in this area.

6.3.3 Adaptation of control strip for sheet-fed offset
Gray balance is critical for good color reproduction, and is a function of ink hue, ink film thickness and the percentage of dot area being printed. It is also affected by color sequence, ink trapping, press characteristics and dot gain. Proper gray balance ensures that a tone of appropriate cyan, magenta and yellow tint values is visually perceived as neutral gray (FTA, 1984). Newspaper printing can be controlled by gray balance, a procedure which is widespread among newspaper printers in Sweden. In sheet-fed offset today, there is no fast and easy way to check a sheet-fed offset-press during production without using advanced time-consuming online-systems.
This study has shown that:

a) The gray balance can be used as a control parameter for control of quality in sheet-fed offset. This assumes of course that the printer has proper visual color vision.

b) A faster make-ready time and more reliable print quality (fewer variations during production) can be achieved.

c) The printer and the customer have access to a tool which facilitates communication, generates fewer misunderstandings, leads to less product returns, etc.

6.4 Standardization as an adaptation
Standardization is essentially an act of simplification (Sanders, 1972) which can be useful for the involved parties. The standards can facilitate the communication because of clearly defined target values. If the printing company decides to print according to printing standards, the company must adapt some parts of the production in some way to come within the limits of the standard. According to the author, adaptation to different equipment, images, printing strips, etc. is not in conflict with standardization. If a company can achieve smaller deviations than standardization recommends then the reproduction of images can be more successful. Adaptation demands knowledge and knowledge leads to better understanding which can impact the entire production in a positive direction.
Conclusions and discussion

7 Concluding remarks

The research presented in this thesis was applied practically, and resulted in a patent concerning image adaptation, surveys of the knowledge level concerning understanding of color management, a communication list concerning ICC-profiles, an educational kit, and a proposal for a new separation terminology.

The research has indicated a serious problem in the graphic arts industry related to insufficient knowledge of color management and lack of communication. With regard to knowledge, there was a lack of competence and a shortage of literature and instructions which could help printers to better understand the technology. There are many graphic software and graphic equipment on the market. Vendors use their own algorithms for their products and as it is very difficult to get these algorithms this results in the need for trials and exercises. For example universities, research centers and other graphic technical associations have to help the users and the graphic field to clarify the processes, the standards, the definition and contribute in this way to a better understanding which can lead to a better reproduction of images.

Learning is a pre-requisite for competence. Learning is not about "processing information" - a computer does that better. Learning is about integrating information and knowledge and use it in the best way.

Åsa Lundquist-Coey
8 The author’s contribution to the papers

**Paper I** - Enoksson Emmi

“The Image Classification and Optimized Image Reproduction”
The entire study was carried out by the author.

**Paper II** - Enoksson Emmi, Aviander Per

“The characterization of input devices by luminance and chrominance”
The author Emmi Enoksson has carried out the research in the paper together with Per Aviander. Emmi came up with the initial idea, planned all trials and did almost all measurements. Emmi was also responsible for the writing of the paper. Per Aviander was responsible for the translation in to English. Emmi was responsible for the presentation of the paper.

**Paper III** - Enoksson Emmi

“Image Reproduction Practices”
The entire study was carried out by the author.

**Paper IV** - Enoksson Emmi

“Digital Test Form for ICC-profiles”
The entire study was carried out by the author.

**Paper V** - Enoksson Emmi, Aviander Per

“Demand specifications for controlled color reproduction”
The author has carried out the research in the paper together with Per Aviander. They have mutually visited several printing houses and conducted many interviews with the personnel. Emmi has gathered and compiled all the answers and suggested “The communication list”. Emmi has also written this report and Per Aviander has translated it into English. Emmi was responsible for the presentation of the paper.

**Paper VI** - Enoksson Emmi, Bjurstedt Anders

“Compensation by black - a new separation?”
The author has carried out the research in the paper together with Anders Bjurstedt. Emmi developed the initial idea, planned all the trials and did all the measurements and analyzed the results. Anders Bjurstedt wrote the history part in the paper. Emmi was responsible for the presentation of the paper.
Paper VII - Norstedt Sofia, Kolseth Petter, Enoksson Emmi
“Using Gray-Balance Control in Press Calibration for Robust ICC Color Management in Sheet-Fed Offset”

The author has carried out the research in the paper together with Sofia Norstedt and Petter Kolseth. Sofia Norstedt has been responsible for the research and she has done all the trials and measurements. Emmi has supported the initial idea, planned the trials and aided in making the conclusions together with Sofia Norstedt and Petter Kolseth. Sofia was responsible for the writing and for the presentation of the paper.

Paper VIII - Enoksson Emmi, Ullberg Jonas
“Gray Balance Control in Sheet-Fed Offset Printing”

The author has carried out the research in the paper together with Jonas Ullberg. Jonas Ullberg has been responsible for the printing possibility. Emmi has planned the trials and was responsible for all the measurements and analyzed the results. Emmi has written this paper and she has presented this paper at the conference.
Appendix - Central concepts and terminology

**AppleScript**

AppleScript is an English-like language used to write script files which automate the actions of the computer and the applications that run on it. It is much more than a macro-language that simply repeats your recorded actions, AppleScript can make decisions based on user interaction or by parsing and analyzing data, documents or events. (www.apple.com)

**Additive color system - see also Color systems**

The additive color process begins with black, or the absence of light and therefore no color, and it involves transmitted light before it is reflected by a substrate. Adding and mixing the three primary wavelengths of light (red, green, and blue) in different combinations produces a full spectrum of colors. Adding all the primary colors in relatively equal amounts produces “white” light, Figure 51. Computer monitors, television screens, projection TV, and stage lighting are based on additive color mixing (Adams, Weisberg, 1998)

\[
\begin{align*}
\text{Red} + \text{Blue} &= \text{Magenta (secondary color)} \\
\text{Blue} + \text{Green} &= \text{Cyan (secondary color)} \\
\text{Green} + \text{Red} &= \text{Yellow (secondary color)} \\
\text{Red} + \text{Green} + \text{Blue} &= \text{White}
\end{align*}
\]

![Additive color system diagram](image)

Figure 51: A visual explanation of the additive color system. (Enoksson, 2005).
Achromatic reproduction
Conventional reproduction is chromatic, i.e. the colours are made up, in particular, of the three colours C, M and Y. Black is used only to create contrast in pictures. In achromatic reproduction, a part of the colours is replaced with black. This gives a clearer print and less set-off. (http://www.ddpff.dk)

Adobe Systems
Adobe Systems Incorporated is an American computer software company headquartered in San Jose, California, USA. The company has historically focused upon the creation of multimedia and creativity software products, with a more-recent foray towards rich Internet application software development.

Adobe RGB, see Color gamut

Bayer interpolation
The digital sensor in the majority of digital cameras is what is known as a Bayer pattern sensor. This relates to the arrangement of red-, green- and blue-sensitive areas. Figure 52 shows a typical sensor. Each pixel in the sensor responds to either red, green or blue light and there are two green-sensitive pixels for each red and blue pixel. There are more green-sensitive pixels because the eye is more sensitive to green, so the green channel is the most important. The sensor measures the intensity of light falling on it. (http://photo.net/learn/raw)

Calibration
The adjustment of a color production device (scanner, monitor, printer) to match an established performance specification or standard (Field, 2004).
CIE
Commission Internationale de l´Eclairage (the International Commission on Illumination), an international standards-setting organization for colorimetry and related optical radiation measurements (Field, 2004).

CIELAB color space
The 1976 CIE color space transformation with the dimensions L*, a*, and b*, in which equal distances in the space represent approximately equal color differences. CIELAB, or CIE L*, a*, b*, is a three-dimensional plot calculated from CIE XYZ tristimulus values, in which L* is lightness, a* is the red-green axis, and b* is the yellow-blue axis. The CIELAB color space has been widely adopted for surface color measurement applications (e.g. printed products) (Field 2004).

CIE XYZ
A set of three values describing the color of an object, based on a standard illuminant and observer, provides the “raw” color measurement data used to make ICC-profiles.

Color cast
A color´s tint deviation, such as yellowish green, pinkish blue, reddish gray, etc. Usually refers to a distortion of hue (Field 2004).

Color gamut
The range of colors which can be formed by all possible combinations of the colorants used in a color reproduction system (Field 2004).

Example of working color gamut: sRGB, AdobeRGB, Color Match RGB, Figures 53 and 54. Different RGB color profiles differ from each other (CMYK color profiles do so also) by size, gradation (or gamma), saturation and to some degree hues for red, green, blue, cyan, magenta and yellow. These differences affect the color conversion, even if the conversion (separation) is to the same CMYK color profile.

Adobe RGB
Adobe RGB has a larger color space than Color Match, Figure 48. This color space is today the most frequently used RGB-standard in the production of print media. Adobe RGB is a relatively large color space, and only a few monitors can display all of its colors. Gamma 2,2, D65. (Johansson, Lundberg, Ryberg, 2006)
ECI RGB

ECI RGB is a relatively new standard developed by European Colour Initiative (ECI) and has approximately the same color space as Adobe RGB (1998). (Johansson, Lundberg, Ryberg, 2006)
sRGB
The sRGB standard, developed by Hewlett-Packard and Microsoft, is based on the HDTV standard (High Definition TV = TV standard with high quality). Hewlett-Packard and Microsoft use sRGB as a standard for office software as well as for web browsers. sRGB is based on the color space which a normal PC monitor can display. However, this is also the limiting factor for the sRGB. Its color space is smaller than to other RGB-color spaces normally used in graphical productions, and it is not suited for images which are to be printed, as large areas of the CMYK-color space are outside this color space. Gamma ca 2,2, D65. (Johansson, Lundberg, Ryberg, 2006)

ColorMatch
ColorMatch is based on the RGB color space which can be displayed by a Radius Press View monitor. Radius monitors were previously commonly used in professional graphical productions, but they have a relatively small RGB color space, and are not optimal for graphical purposes. Gamma 1,8, D50. (Johansson, Lundberg, Ryberg, 2006)

Color systems: RGB and CMYK see also Additive systems
The graphic industry uses two main color mixing systems: the additive system RGB (the primaries colors are red, green, and blue) and the subtractive system CMY (the primaries colors are Cyan, Magenta, and Yellow). Both systems are device-dependent systems. This means that the reproduced color is dependent on the device, the condition of the device, the age, the structure, the pigment, the substrate, etc.

Color separation
The process of making intermediate images from the color original to record the red-, green-, and blue-light reflectances. These images are used to prepare the cyan, magenta and yellow printing records. A black separation is also made. (Field, 2004).

Conversion
Translating a colour image from the colour space of one device to that of another. More rigorously known as colour conversion. (Adams, Weisberg, 2000).

CMYK - see Color mixing systems
DeltaE, ∆E, - deltaE, a measure of color difference in CIELAB space (see CIELAB), is calculated using a distance formula to determine the distance in color space from one color to another (Adams, Weisberg, 2000)

Formula: Delta E:

\[
\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}
\]

where:

L_1^*, a_1^*, b_1^* = CIELAB coordinates of reference color
L_2^*, a_2^*, b_2^* = CIELAB coordinates of comparison color

**Dot gain**
Net percent increase in halftone dot size (or tone value) through the tone scale or at a specified percentage (e.g., 50%). A dot gain of 20%, then, signifies that a 50% tint reproduces as 70% apparent dot area (Adams, Weisberg, 2000).

**Density**
The ability of a material to absorb light. Expressed as the logarithm (base 10) of the opacity, which is the reciprocal of the transmission or reflection of a tone. (Field, 2004)

**Gamma**
The ratio of the contrast range of all or part of the reproduction to the corresponding contrast range of the original, see Figure 55. A gamma of 1.0 means that the reproduction has the same contrast range as the original (Field 1999).

**GCR - Gray Component Replacement**
GCR - a means of producing more consistent color and increased shadow detail in a printed reproduction by reducing the sizes of the cyan, magenta and yellow halftone dots which contribute to the darkening effect-or gray component-of an image. This has the effect of lightening an image without changing the actual colors reproduced, and the size of the black dots is increased to compensate for the gray removal (Romano, 1998). For a more detailed explanation see Paper VI.

**ICC, International Color Consortium**
A committee formed in 1993 to establish specifications and guidelines for manufacturers and developers of software, equipment, and producers related to color management systems (Field, 2004).
IT.8
Information Technology, an ANSI-accredited committee that developed three standard targets for input and output profiling, collectively covered by Standard IT8.7:IT8.7/1, scanner transparency target; IT8.7/2, scanner reflection target; and IT8.7/3, CMY(K) output target (Adams, Weisberg, 2000)

JPEG (Joint Photographic Experts Group)
Data format and compression algorithm for color images. Often used in digital cameras (photography). Offers advantages for Internet applications due to the relatively small amounts of data involved.

MAC OS X
Mac OS X is an operating system used since 2004 by Macintosh-based computers (Johansson, Lundberg, Ryberg, 2006)

Posterization
When performing image manipulations such as tonal conversions in low bit environments (e.g. 8bits/channel mode) only a limited number of tones may be available to describe a certain area of the image. This causes visible ”banding” or ”posterization”. (www.dpreview.com).
**Subtractive color system** - see also Color mixing systems

The subtractive color process is based on light reflected from an object and which has passed through pigments or dyes that absorb or “subtract” certain wavelengths, allowing others to be reflected. The primary subtractive colors - cyan, magenta, and yellow - can be combined to form red, green, and blue as secondary colors, Figure 56. Combining the ideal subtractive primaries in equal amounts produces black (Adams, Weisberg, 1998). CMYK (K = black = key color) is used for printing (output devices).

![Figure 56: The primary colors are cyan, magenta and yellow and the secondary colors are red, green and blue.](image)

**Rendering Intents**

When converting from RGB- to CMYK-mode in Adobe Photoshop, the user can decide which rendering intent to use: Perceptual, Saturation, Relative colorimetric, and Absolute colorimetric. The rendering intent decides how a colour management system handles the colour conversion from one colour profile (or gamut) to another.

**Perceptual:** The relationship between colors is retained, Figure 57. The perceptual rendering intent is used for photographic images with a very good result. The most pleasing result is mostly obtained if we do not distort the relationship between colors (Sharma, 2004).

Perceptual rendering compresses the out-of-gamut colors into the gamut of the target space in a rather generalized way, while preserving the visual relationship between those colors, so they do not clipped (Evening, 2007).

**Relative rendering:**

The relative colorimetric is the default rendering intent utilized in the Photoshop color settings (Evening, 2007). With the relative intent, the colors outside the destination gamuts are clipped and forced to the gamut boundaries, Figure 58.
In absolute colorimetry the white point in the image is not allowed to change. Absolute colorimetric maps in-gamut colors exactly from one space to another with no adjustment made to the white and black points (Evening, 2007). This intent is used in situations where we wish to make side-by-side comparison (Sharma, 2004). In the example, Figure 59, the girl’s cap is yellow in the original and yellow in the reproduction.
Relative colorimetry takes into account the white point of the destination substrate. In relative colorimetry, the white point is allowed to change. The original may have a yellow paper base, while the reproduction may be printed on a bluer paper stock. Using relative colorimetry, the girl’s cap is yellow in the original and blue in the reproduction (Sharma, 2004). Figure 60.

Figure 59: In absolute colorimetry, the white point in the image is not allowed to change. (Enoksson, 2005)

Figure 60: In relative colorimetry, the white point is allowed to change (Enoksson, 2005).
RGB - see Color systems

Setoff
The undesirable transfer of wet ink to the following sheet in the delivery pile of a sheet-fed press. (Field, 2004)

TIFF (Tagged/or Tag Image File Format)
The most common pixel format; it is supported by virtually all systems. Among other things, this format is suitable for the data exchange of color images and gray values as well as various levels of resolution and sizes.

Tertiary color
In color printing, the color produced by overprinting secondary colors, or all three process colors. (Romano, 1998)

TIC - Total Ink Coverage,
As process color ink pigments are imperfect, pure black cannot be achieved by overprinting CMY inks. Consequently, black (K) ink is introduced in addition to, or as a substitution for, CMY inks. The combined value of all CMYK inks for a particular area or object cannot exceed a specified amount, or ink may not transfer effectively and printed sheets may not dry properly. This specified amount, referred to as the Total Area Coverage (TAC), is typically limited to 300% for offset lithography using coated paper. Compensation for TAC limitation is accomplished during the conversion from RGB to CMYK, by means of UCR (undercolor removal) or GCR (gray component replacement). [http://dx.sheridan.com/advisor/tac.html]

Trapping
The ability of an ink to transfer wet-on-wet, i.e. the ability of an ink to transfer equally well to both an unprinted substrate and a previously printed ink. (Field, 2004)

UCR - Under Color Removal
A technique used to reduce the magenta, cyan and yellow dot percentages in neutral areas and replace them with a suitable amount of black ink (Romano, 1998). For a more detailed explanation see Paper VI.
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