Factors Influencing Image Quality in a Digital Workflow

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Abstract: The factors that influence the image quality in the digital workflow have been studied at a number of different graphic art service providers. All of these companies have two digital workflows:

1. Image originals delivered by the customer and scanned at the service provider to CMYK-files.
2. RGB- and CMYK-files delivered by the customer to the service provider.

The two workflows contain different functions but have the same goal: to make the reproduced image as similar to the original as possible and to match the customer's specifications.

Tests have been carried out, with the objective to identify the primary factors that influence image quality. Further, methods of equalizing the functions in the different workflows have been evaluated. The possibilities of reorganizing and automating the workflows or parts of them have also been analyzed. Interviews with customers have been carried out in order to establish which quality factors they consider as the most important.

The study has shown that the different workflows give different results. It also shows that it is possible to reorganize the two different workflows into one to achieve more consistent and predictable image quality. Many of the functions in the digital image workflow can be automated if the images are classified and prepared correctly.

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Introduction

The production technologies in the graphic art industry are rapidly moving from proprietary systems to a standard computer platform in an open production environment with standardized computer peripherals. This means that players in the graphic arts industry market can no longer conduct a business around hardware investments and a static customer base. The players have had a clear definition of their business which have been closely related to their hardware investments. Examples of such businesses are photo laboratories, prepress houses, image bureaus, print houses and so on. Today we collectively call them GASP, Graphic Arts Service Providers. The services they offer are dependent on their customers' demands. The demands change when the customers markets change which makes it crucial for the GASP of today, and of tomorrow, to be able to alter its services. The production tools are becoming more similar for all of the GASP. New tools are developed at a fast pace resulting in new possibilities to automate the processes. The major factors of success for the players of today and tomorrow are the ability to change and understand the customers' market. The market demands shorter delivery times and lower costs. The total number of printed editions is diminishing with an increasing number of pages and images. At the same time, the customers require higher quality with the ability to predict and control the end result.

This paper is a partial result of the research project "Digital Image" carried out at the Institute of Media Technology, Department for Digital Communication and Multimedia, Stockholm, Sweden in association with the Royal Institute of Technology, Division of Media Technology and Graphic Arts, Stockholm, Sweden. The objective of the project is to analyze the prepress production process to find potentials for increasing productivity and quality. The activities that influence productivity as well as quality and changes due to new technologies and new customer demands will be identified.

Methods

In the project "Digital Image", there are eleven active companies. They are all companies in the graphic arts industry, and traditionally one can say that they fit in the following categories: commercial print houses with both web and sheet fed printers, prepress houses and image bureaus. We have mainly used information from the participating companies, which we have gained during one year (1997) of continuous contacts. These contacts have been through telephone interviews,

workshops, observations at all companies and analysis of production data. Open-ended interviews have been conducted with both operators and managers. Each prepress department at the participating companies has been thoroughly mapped. The data collected has been reported back to the participants for review and validation. Workshops based on collected data have been conducted with the participating companies to jointly analyze their status and possibilities. Furthermore, both qualitative and quantitative studies of actors interacting with prepress, i.e. advertisement agencies, publishers, digital photographers, as well as other printers and prepress houses have been conducted. The selection of companies we have interviewed and analyzed has been chosen on the bases that they should be companies in the front-line of the graphic art industry when it comes to technology and organization.

From an American mailing list [ctpp, 1998] with 800 members involved in the graphic arts industry, we have followed topics concerning prepress. We have also used it as a forum for discussing questions applicable to our research. Through this mailing list we see how prepress is developing from an international perspective. The observation we have made is that the industries are developing in the same direction and the questions under debate are applicable for the Swedish GASP. International scientific journals and exhibitions in Graphic Arts are also part of the knowledge base in our research. We therefore find the results from this paper to be applicable on prepress departments and companies internationally.

Initial tests

Tests with two different motifs on different media such as 35 mm negative film, 35 mm transparencies, medium format transparencies, RGB files and CMYK files were conducted at four of the participating companies. The objectives of the tests were to establish how the GASP processed the different images and how similar the end results from the different media became. Our assumption was that the tests could be used to compare the end results from the different GASP and thereby establish a relative measurement of image quality delivered by the companies digital image workflows. The results from the tests show that all GASP presented different results from the different media. Visual comparison stated that no GASP got better overall quality. They all managed to present one good match to each of the original transparencies. There was not one specific type of media that gave the good match, it varied with the operator and GASP. In other words,

with equipment and knowledge. No GASP had static processes (processes with predetermined fixed parameters) or documented guidelines on how to process their images. The images were processed according to the operators knowledge and experience. Since all GASP had more than one operator and no guidelines, the possibility to produce repeatable results was poor. The possibility to produce matching results from different media, as stated above, was even worse. The assumption that we could establish a relative measurement of image quality based on the tests proved to be wrong. But the tests generated valuable information about the factors that influence the overall image quality at the GASP studied. From all factors that influenced the final image quality in the digital image workflows, the lack of static processes was one of the two most important factors. The other was customer value, see the section Quality = Customer value.

Today's Workflows

The two workflows, described in this section, are representative for all companies studied. They are the main workflows, specific jobs can have slightly different workflows from the ones discussed in this paper. All companies studied used physical folders containing the complete order including order form, specifications, analog images, different media containing all digital files. These folders were assembled by customer contact persons. When an order folder was complete with order specific information, lay-outs, logotypes, and images it was then given to the scanning staff. Analog originals were scanned with settings adapted to the final product. Filesize, colorspace, grey balance, tonal range (determining highlight and shadow), hue, saturation, contrast, sharpening, dot gain, fileformat and other specific settings were set as the images were being scanned. They were set for each image one by one. Predetermined values (not documented) for some of these settings were used in limited sets for different originals. The main settings that were different for all originals were tonal range, grey balance and filesize. Image manipulation were made at a later stage on different workstations from the ones used for scanning. All images scanned were opened, checked and if necessary manipulated at these workstations before being saved to a "done" folder at the server. A sketch of the image workflow for analog originals is shown in Figure 1 (circles indicates objects and rectangles indicates processes).

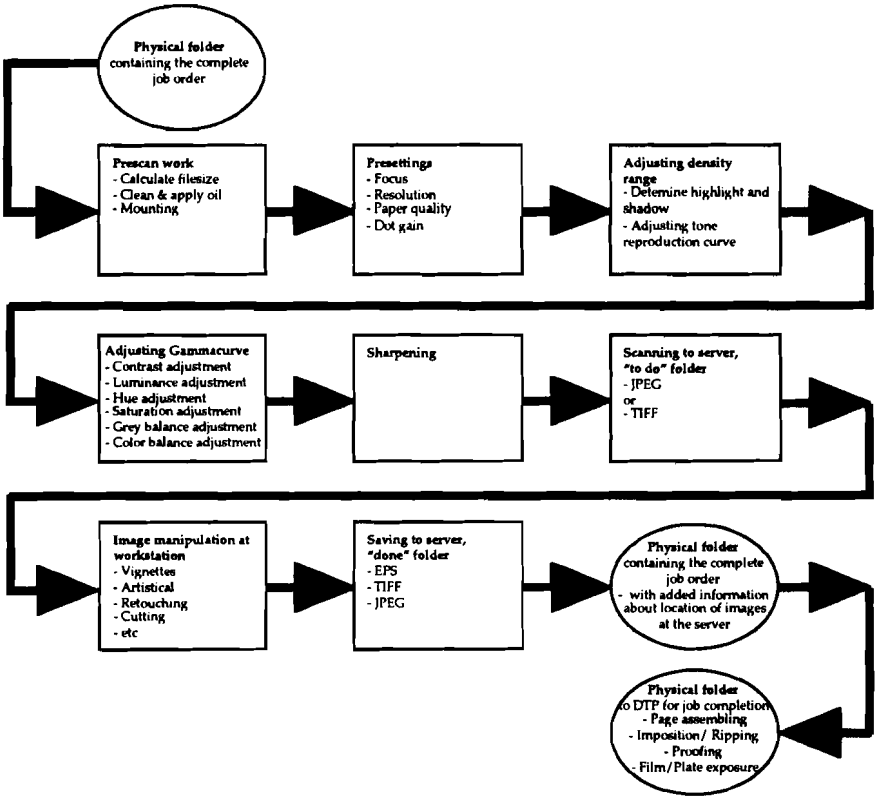

Figure 1. Workflow for analog image originals

The digital images provided by the customers passed through a different workflow, see figure 2. They were delivered mainly on magnetic discs or tapes, optical discs, compact discs, via ISDN or as attachments to e-mail messages. Information about where the digital files were located, sizes and special requests from the customer were provided in the physical folder together with the physical media. All digital images were opened, imported or created on a workstation sequentially. The RGB images were initially convert to CMYK. All the companies studied used Adobe® PhotoShop® software for this conversion. The main reason for this was that the images have to be opened in Adobe® PhotoShop® in the following step of the workflow. Therefore using other software for CMYK conversions seemed to only add an extra step in the workflow. Tests with other software (Binuscan ColorPro®, LinoColor® and others) for CMYK conversion have been carried out by most of the companies. They were not used in the production environment because of the effect on productivity, since two

software products have to be used instead of one. The settings in Adobe® Photoshop® for the CMYK conversion varied among the companies. Seven out of the eleven companies studied used the standard settings for Euroscale provided with the software, three had simulated the tone reproduction curve used when scanning analog images and one company used Apple® Colorsync® profiles. After CMYK conversion the image passed through a similar workflow as the analog images. Filesize, grey balance, tonal range, hue, saturation, contrast, image manipulation, sharpening, fileformat and other specific settings were all done before the images were saved to the servers "done" folder. Each image was completed sequentially. Predetermined values (not documented) for some of the settings were used dependent on the original. The main settings that were different for all original were specific image manipulation, tonal range, grey balance and filesize. A sketch of the workflow for digital image delivered by customers is shown in Figure 2.

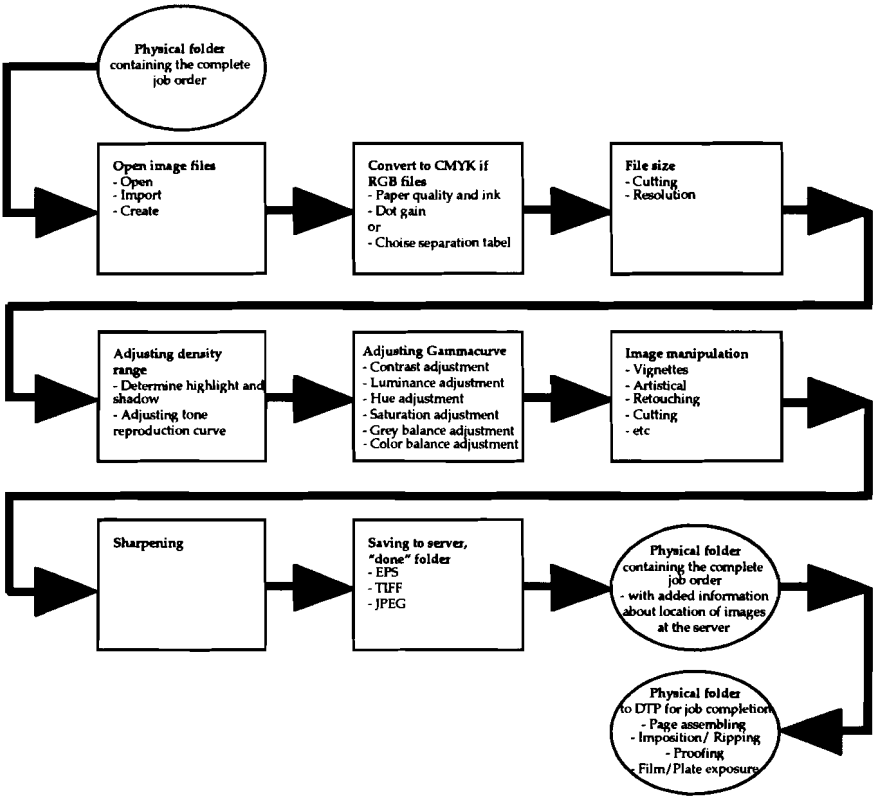

Figure 2. Workflow for digital images delivered by customer

The physical folders were passed on to the next process in the prepress workflow when all the images, digital and analog, were processed and made ready for print.

The workflows described have three major drawbacks. The first is that they give different results compared to each other, because the use of different software and settings. The second is that since all the settings are set manually with no guidelines or regulations it is impossible to measure the overall image quality resulting from the workflows and therefore impossible to measure quality improvements. The third is that all images in the physical job folder have to be completely processed and made ready for print before the folder is passed on to the next process in the prepress workflow. The study has shown that the scanning and image preparation process is a bottleneck in the prepress workflow which therefore will affect the complete prepress workflow.

Measure and Automate

Since no report, known to the authors at this moment, has proved that it is possible to fully automate the image workflow it is easy to reject the idea of automating the image workflow. We argue that this is one of the main reasons for the lack of controlled and partly automated image workflows. Why bother if it is not possible? One reason we find for GASP to focus on automation and control of image processes is that it is one way to measure quality delivered from the image workflow and thereby increase the possibilities of improving that quality. To be able to increase quality it has to be put in measurable terms. To meet objectives without the possibility to adequately measure will give incorrect results. To measure the final results from the image workflow one can, according to White (1975), use either instrumental (objective), panel (subjective) or statistical approaches. White (1975) presents the Print Quality Index which is a combination of the two last ones. The limitation of these methods are that they all are post-image workflow measurements. They can deliver results that can be used to convince the staff that they have to produce higher quality, but they do not deliver solutions on how they could achieve that. The methods can on the other hand be used to measure results from improvements made within the workflow.

Our study has show that the scanning staff uses a limited number of settings when preparing images for reproduction. When visually examining the originals to be scanned or the digital images on screen,

they decided what to do with the images. The decision was based on their experience which helped them to choose an appropriate process. A major part of the original were processed with similar settings. A first step to be able to automate processes in the image workflows is to document these settings. After finding and documenting the settings for each image reproduced the settings can be evaluated and compared. Similar settings can then be collected into categories based on why the settings were used and what type of images they were used on. For example Too dark, Too light, Too blue, Too little contrast, General transparency, Customer 1 (if the customer always want the images to have saturated colors, more contrast or other fixed special requests) and so on. These categories of settings can then be a base for the development of automatic static image processes. When the scanning staff visually examines the analog originals or digital images on screen they now decide, using their experience, which static process the image should be processed through. Once a set of static processes are used they can be evaluated, compared and improved using for example the Print Quality Index. This method is iterative and should constantly be improved. Both the specified setting in the static processes and the amount of static processes should change over time and with the customers' demands. The objective for the image workflow should be to automate all of its processes and to establish a sophisticated process selection method. We propose that this will be the major future work assignment for scanning and imaging staff.

As mentioned earlier we cannot prove that it will be possible to process 100% of the images through automatic static processes. We argue that even if just a part of the total number of images can be processed automatically it will be useful. It will give the GASP a possibility to evaluate images and their quality based on if they are possible to process automatically or not. When an image is classified as not being possible to process through any automatic static process the staff will specify why it was not possible. These specifications can over time be collected into categories and then be used to develop new static processes. Even if some of the specification are, today impossible to turn into automatic static processes it will give the GASP a tool to classify the quality of images delivered by the customers. Example of quality classes could be: automatic process, partly automatic process, manual process and so on. This could then be a GASP's tool for production planning, differentiated prizing and image quality communication with the customer.

Quality = Customer Value

We have separated quality into two parts, which we call production quality and customer value. To explain this we refer to some definitions of quality. Quality is by ISO standard 8402 defined as: " Totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs". Quality is therefore not an absolute value but always depends on the customers expectations. It is often described as: "Quality is fitness for use". (Schnitzler and Has, 1997). "In other words, quality strategy is chosen to suit the circumstances" (Field, 1996). This implies that even if the production quality of the images, that can be measured with methods mentioned in the section Measure and Automate, is considered to be high, the service provided is not necessarily considered as high quality service by the customers. It is therefore important for the GASP to consider the customer value of the service provided and not only the production quality of the images. We have conducted a number of open-ended interviews with large customers to the graphic art industry. The objective was to establish what they considered to be the most important factors that influenced image quality, delivered from the GASP they used. With large customers we mean customers having several different print productions and using several different GASP for these productions. The results of the interviews show that very little consideration was taken to production quality. After structuring the results from the interviews three major areas could be found that the customers considered to influence the overall digital image quality the most:

1. Knowledge. The customers were of the opinion that the GASP either had good knowledge about graphic arts or good knowledge about computer technology but very seldom both. This caused many of the image quality problems, according to the customers.

2. Communication. Misunderstandings and loss of information was another major contributing factor in not receiving the image quality expected. The customers requested faster and easier communications.

3. Throughput. The slow throughput of the prepress workflow was seen as one reason for not achieving the required results. Orders were not processed directly which caused information loss. The customers also wanted faster delivery times and faster procedures for approval of proofs.

With these results as a base, questionnaires about overall digital image quality were made. The questionnaires were reviewed by the interviewed customers and different GASP (including all participating companies) to assure that they accurately covered the areas of digital image quality. These questionnaires were then used in a test with two GASP (here called GASP 1 and GASP 2). The questionnaires were sent to ten major customers of each GASP. The results from the questionnaires show that the customers of GASP 2 were more satisfied with the image quality than the customers of GASP 1 were. This by itself is not very useful but after comparing the production quality of the two GASP it shows the importance of customers value and not only production quality.

GASP 1 is a print house with prepress in-house and specialized in catalog production. Sixty-five percent of the total production is product catalogs. The success of the customers' business is depending on how much sales these catalogs generate. The image quality and its match with the physical product is therefore considered to be crucial.

GASP 2 is also a print house with prepress in-house but specialized in internal staff magazines for government organizations, unions, associations and others. Seventy percent of the total production are internal staff magazines. The success of these magazines is based on providing employees with accurate and interesting content. The content of the articles is considered more important than the illustrations, images and the lay-out.

A visual comparison of printed products from the two GASP showed that GASP 1 had by far the best production quality. A laymen could easily see that the image quality delivered from GASP 1 was superior to the image quality delivered by GASP 2. A standard product from GASP 1 had clear, contrast rich and sharp images. The standard product from GASP 2, on the other hand, had smudged, low contrast and unsharp images. Still the customers of GASP 2 were overall more satisfied both with the image quality and the service in general. This is just one example of the importance of customer value. We argue that a GASP with high customer values in the areas Knowledge, Communication and Throughput will have a lower risk of losing their customers. They will also have a greater opportunity to develop themselves together with their customers and their changing demands.

Reorganized Workflow

A reorganized workflow should consist of limited sets of static processes. These processes should be able to be automated and easily altered according to customers demands. Furthermore, the workflow has to meet or exceed expected customer values on Knowledge, Communication and Throughput. A sketch of a reorganized workflow for analog and digital images is shown in Figure 3.

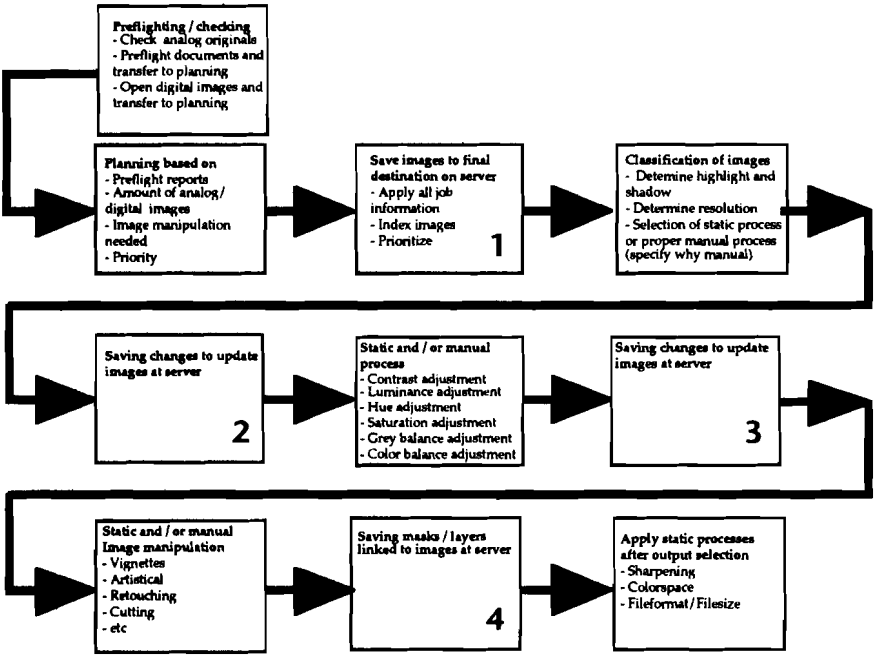

Figure 3. Reorganized workflow for analog and digital images

The complete order (including all documents, images, logotype etc., digital and analog) provided by the customers should be preflighted. Preflight is a general term used in the graphic art industry for the process of checking analog originals and digital files before sending them for further processing. Digital files can be preflighted with preflight software such as, for example, Markzware's FLIGHTCHECK®. Planning staff shall then sort the jobs to a central server and, if necessary, to a physical folder (analog originals). Information about where the digital files and the physical folders are located and all order specific information should be available in a digital format, on the central server. The planning staff can now

priorities and distribute work orders to the prepress organization based on processes needed. Scanning staff will scan and open images to and from the server location determined by the planning process. The resolution of the images should be set to match the most common format used. It should be chosen so it will require a minimum of re-scans when used in multiple productions. After opening or scanning the images only tonal range will be set. Then the scanning staff determines which process is needed for each image and saves the image into that process's "to do" folder. If an image is classified as not being able to be processed through any automatic process it should be placed in a manual process folder. The reasons for not being able to be automatically processed should be documented together with the other information about the complete order. The image will, after it has been processed, replace its original file at the central server. The images are at this point not adjusted for a specific output device. They are saved in a device independent format and are adjusted to be a digital original which can be reproduced at different outputs. They should have the following qualities (Field, 1988): a tone reproduction curve that favors the interesting area in the photography; color balance to achieve good neutrals; preferred skin and sky colors that are deliberately distorted from the original scene; correct saturation of important color areas; high resolution; low graineess; minimal moiré; appropriate sharpness; high gloss; and perfect smoothness. The last four qualities are taken in consideration later in the workflow, when choosing a process depending on the output device. The next process in the image workflow is to apply image manipulations requested by the customers. Manipulations made shall be saved as masks/layers and not to the image file on the server. They shall be applied when the images are being processed for a selected output. This will leave the digital original on the server untouched, which makes it possible to use that image with new settings in another production. The images are thereby adjusted for reproduction with mask/layers linked to the images for the manipulations requested. The last process is to adjust the images for the final output. Static processes have to be chosen to fit the output device. The appropriate filesize (resolution), sharpness, reproduction curve/color space (i.e. ICC profiles) will then be applied.

The advantages of this kind of workflow is, for example, the ability to place images into a layout at an earlier stage of the process. The boxes with the numbers 1 - 4 in the lower right-hand corner, indicates that the images are accessible for other operators. Since there is only one original image file on the server, lay-out operators can start to place the images into a lay-out before the image is completely adjusted. This

will increase productivity and may eliminate the bottleneck of scanning, in other words increase throughput. Customers can also access images in box 1 - 4 based on agreements and what is considered to increase customer value and or productivity. This can make it easier to communicate with the customer and will give the customer the possibility to comment on image manipulations, settings, production quality etc. earlier in the production workflow. It will thereby be easier to evaluate what the customer considers to be added value and not. Since the workflow is based on sets of automated processes, evaluations of those processes can be made on regular basis. These evaluations can be used to increase the quality delivered by the workflow. Working with these evaluations and trying to find solutions for occurring problems, will increase the knowledge of the digital processes and how they affect the image quality. Craftsmen with high skills in traditional image reproduction will have to cooperate with computer skilled technicians to be able to get the static processes to meet set objectives.

Summary

The two major factors that influence image quality in a digital workflow are the lack of static processes and understanding of customer expectations. It is therefore important to:

- Have a flexible and adjustable digital workflow, based on static image processes, which produce predictable and measurable results.
- Understand and match or exceed the customers overall expectations on the service provided.

A reorganized workflow, containing static processes, where the images are saved at a central server in an open format (not adjusted for the final output) will increase both productivity and quality. Productivity will be increased due to easier planning of and better control over incoming orders. It will also increase because of the possibility for parallel production where lay-out and imposition of images can be made although the images are not finally adjusted. Production quality will be increased since the processes are measurable and therefore possible to improve. Customer values will also improve since the reorganized workflow will have a faster throughput, the static processes will give quality classifications that could be communicated to the customer, the customers will be able to take an active part in the prepress workflow and the knowledge of the digital workflow will increase while developing and implementing the static processes.

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