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A Research Monograph of the
Printing Industry Center at RIT

No. PICRM-2011-03

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Abstract

This research investigates the effects that font choice, typographic design, and page layout have on the conservation of ink and paper. This is one part of a broader concern with the environmental sustainability of digital printing. The particular focus of this report is on thesis guidelines for graduate students in the School of Print Media at RIT. The preparation and printing of theses is a salient area of paper and ink consumption at an institution of higher education and research. Established, well-defined thesis guidelines permit precise comparisons of the effects of different typographic factors on materials consumption. Three different aspects were investigated in the preparation and publication of graduate theses in order to determine the amount of reduction possible in paper and ink consumption. A high measurable potential for waste reduction was found.

The first aspect is the modification of typographic parameters—within current established guidelines—to reduce paper use. Following this, changes to the typographic components of the thesis guidelines were recommended to increase paper savings further. The second aspect is the selection of alternative, ink-economical typefaces and fonts to reduce ink consumption. The third aspect is modification of the letter forms of fonts to reduce ink consumption even further while maintaining apparent readability. It was found that measurable, material savings can be derived from changes to all these aspects of thesis guidelines, and it is expected that similar savings may be derived from the applications of similar methods to more general institutional printing.

Introduction

A 2010 announcement, “Going Green with Century Gothic,” by the Computing Information & Technology department at the University of Wisconsin Green Bay, claimed that changing the default font when printing from email and office applications (Microsoft Outlook, Entourage, Word, and Excel) could reduce printer ink consumption by 30%. This announcement also stated that printer ink costs \$10,000 a gallon and constitutes about 60% of the cost of a printed page (“Going Green”, 2010). This announcement, although intriguing, contained very little data or resources and thus sparked several questions about the ink-saving capabilities of different font choices.

Our study—which was inspired by this press release—focuses on investigating the claim of attaining ink savings by font changes, as well as the more general question of how typographic choices affect paper and ink consumption and, in turn, the environmental impact of the goods consumed. The subject of this study is academic document printing at Rochester Institute of Technology (RIT), an easily accessible and broad institution in which to do testing and surveying and also an institution where a large amount of printing is done. The preliminary research showed that the printing of documents is ubiquitous yet so varied in methods, applications, and standards that it is difficult to measure overall ink consumption for every department at RIT. Therefore, the area of study was reduced so that the parameters of printing, ink, and paper consumption could be more precisely defined and measured. In particular, the research was focused on academic printing by graduate students.

The preliminary research strongly indicated that the amount of emails printed by students today is negligible. Email exists in the ether, the cloud, on servers, or on hard drives, but rarely on paper. Other forms of electronic communication such as text messaging and other wireless text media seemed even less likely candidates for printing. Because of the extreme paucity of data on the printing of such texts, these areas of electronic text were omitted from the final research scope. The focus was then changed to areas of academic text, which are created by all students but printed most frequently by graduate students who have print requirements for papers and theses for publication. Unfortunately, typographic parameters, such as margins, font choices, line spacing, headings, and paragraph formatting, vary from course to course and department to department. One form of document, however, for which typographic parameters are usually explicit and well defined is the graduate thesis. Therefore, the scope of this research was narrowed to looking at the effects that font choice and general typography may exert on ink and paper consumption in graduate theses.

A number of different departments at RIT were surveyed to see what kinds of guidelines were in place for graduate students’ theses. Table 1 shows these departments and their guidelines.

Table 1. Thesis guidelines for RIT departments

Department	Typeface	Size	Margins (T x L x R x B)	Spacing
Print Media	Times New Roman or Arial	12 pt.	1.25 x 1.5 x 1 x 1.25	1.5
Electrical Engineering	Not Specified	>10 pt.	1.25 x 1.5 x 1 x 1.25	1.5 or 2
Social Sciences	Not Specified	10-12 pt.	Not Specified	1.5 or 2
Microsystems	Times New Roman	11-12 pt.	1 x 1.5 x 1 x 1	1
Mechanical Engineering	Times New Roman	>12 pt.	Not Specified	1.5
Professional Studies	Not Specified	12 pt.	1 x 1 x 1 x 1	2
Chemistry	Any	10-12 pt.	1 x 1.5 x 1 x 1	2

These guidelines gave us a working understanding of the parameters that could be altered to estimate the consumption of ink and paper under different typographic conditions.

Paper Consumption

Procedure

Our first step in analyzing potential paper savings was to define a target group to study. We determined that graduate students, during their thesis research, writing, and ultimate printing, consume the most paper among students. This determination was based on some rough calculations of known graduate printing habits:

1. Graduate students must have at least two advisors in their committee, and each advisor must receive a hard copy of both the thesis proposal and the thesis for review. *(4 copies total: 2 proposals, 2 theses)*
2. A survey of proposals showed that the average length (for students graduating in 2011) was 20–30 pages. *(80-120 pages total)*
3. A survey of past published theses was made, and an average page length was determined. Because each department varied, the RIT School of Print Media (SPM), which has many theses published each year and clear guidelines for formatting, was selected. The average page length for SPM is 97 pages. *(388 pages of text for the committee)*
4. SPM students are required to have bound copies made of their final, approved thesis. There must be at least one copy for the department and one copy for the library, as well as an average of two or three copies for family, friends, and personal use. Since this number varies from student to student, only the minimum estimate of four copies was taken into account. *(388 pages total)*

This gives the average SPM graduate student a **base total of 856–896 pages printed** during his or her time at RIT. This number is considered a minimum amount printed, as SPM graduate students also print papers for classes, copies of articles and studies for their thesis research, rough drafts of their thesis (possibly in several iterations), and printed copies of the final thesis for editing. Taking all this into account, an average total of 1,000 printed pages per graduate student is a conservative estimate.

These calculations confirmed the original thought that the graduate program was an ideal place to attempt to install a page and ink savings set of guidelines.

In order to determine if it was possible to save paper by adjusting typographic formatting, the guidelines for current thesis formatting had to be defined. Because every department has established their own guidelines for formatting, the styles vary widely. The School of Print Media Master's Guidelines were chosen for the original formatting, as they are among the most clearly defined and specific guidelines on campus.

Currently, the SPM guidelines state the following relevant rules:

1. Font should be Times New Roman or Arial.
2. Text should be double-spaced (except for bibliography, footnotes, and long quotes).
3. Margins are: Top: 1.25" Bottom: 1.25" Left: 1.5" Right: 1."
4. Major headings must be 2" below the top of the page.
5. Long quotations must be indented 1/2" from the left and right margins.

Some of these (rules 4 and 5) cannot be changed, because they are generally accepted formatting rules from the APA style manual (the standard for the department) and for submitting final theses to ProQuest, but the other three are potentially available for adjustment.

To test the kinds of changes that would make a difference in page length, a thesis proposal—which follows the same formatting guidelines as the thesis—was used. Once it was shown that all three of these formatting changes had a noticeable effect on page length, a sample text was created with Latin filler text at a standard thesis page length to test the full effects of the changes. In the School of Print Media, the average thesis length from 2007 to 2010 was 97 pages; this was rounded up to 100 pages to give an even number for calculations.

The sample text was then formatted according to three different sets of parameters: original, which followed the current guidelines in the most page-consuming way; page saving, which continued to use the current guidelines but in a more page-saving way; and super saving which adjusted the formatting beyond what was defined by the current guidelines. The results were then compared to determine the kinds of formatting changes that had the most potential for reducing page use.

Results

Proposal Test

The proposal used for this test included non-adjustable elements such as tables and images, as well as footnotes, page breaks, and a bibliography, all of which will affect the final page reduction. The total beginning page length was 23 pages.

With five simple adjustments to the typography of the proposal, the page count dropped to **17 pages**, a saving of **6 pages** (26%). With minor changes to the thesis guidelines, including a slight change to margin size and font size, the page length is reduced an additional **4 pages** to a total savings of **10 pages** (44%), almost half of the total length.

The typographic changes made are listed below:

1. Change from Arial to Times New Roman.
2. Instead of a line break between paragraphs, use a tab at the start of the paragraph.
3. No line break between heading and start of paragraph.
4. No line break between last paragraph and next heading.
5. Cite with endnotes rather than name and date.

Typographic change #5 was removed after it was determined that such a change may not fall within APA style parameters. The next stage was to test these changes on a full thesis-sized block of text, with non-adjustable elements removed for more accurate results.

Thesis Test

For this test all the graphical and non-adjustable elements were removed, leaving a uniform body of text for more accurate measurement of the amount of reduction in pages. The three stages of changes were defined as follows:

- “Original:” The original text block with Arial font, double spaced, extra line space between paragraphs, and the original margin settings.
- “Page-Saving:” The first stage of adjustments made that fall within the guidelines.
- “Super-saving:” Additional changes to the document that would require permission from the Dean to use, as they fall outside of the guidelines.

With only **3 changes** (from the original document to “page-saving” settings), there was a savings of approximately **36%** of pages. With two additional changes in formatting to the “super-saving” settings, an additional savings of **12%** occurred, for a total of **48%** page reduction. With the first page-saving adjustments, there was no change

to the generic thesis guidelines as defined by RIT. Although thesis guidelines vary by department, the consensus is a font of Arial or Times New Roman, double or 1.5 spacing, and a 12-point font. To gain greater savings, the font size is reduced slightly, although this still falls within the guidelines of some departments, and the top and bottom margins are reduced by a quarter-inch each (see Table 2).

Table 2. Page saving format changes on a 100-page sample text

Formatting Options	Original (100 pages)	Page-saving (63.5 pages)	Super-saving (51.2 pages)
Typeface	Arial	Times New Roman (8 pages*)	Times New Roman
Spacing	2	1.5 (23 pages*)	1.5
Paragraph Spacing	line spacing after paragraph (24 pt.)	no line spacing, tab at beginning of paragraph (7 pages*)	no line spacing, tab at beginning of paragraph
Size	12 pt.	12 pt.	11 pt. (9 pages*)
Margins (T x L x R x B)	1.25 x 1.5 x 1 x 1.25	1.25 x 1.5 x 1 x 1.25	1 x 1.5 x 1 x 1

* Amount of pages saved per formatting change is rounded up to a whole number.

Real Text Sample

Because pseudo-Latin filler text has very few descending letters, it was decided that the final test for page saving would be done on a real block of text. The text selected was a set of Sherlock Holmes short stories available in the public domain on the Gutenberg Project website (<http://www.gutenberg.org>). The text was extracted from the archival file, and all the chapter headings and short one-liner dialogue were removed in order to more accurately simulate a thesis text block. Next, the same formatting changes were made to the document. At this stage, a new font choice, “DejaVu Light Thesis,” had been created, and so a second set of measurements were taken, where DejaVu replaced Arial and Times New Roman. Century Gothic, which was the recommend font in the original press release, was also used as a comparison (see Table 3). As can be seen in Table 4, the percentages for page reduction in DejaVu vs. the original change are very close, differing by only a few pages.

Table 3. Results of formatting changes on actual text with Century Gothic font

Format (total page count)	% Change (from 100 pages)
Century Gothic Original (114.2 pages)	+14.2%
Century Gothic “Page Saving” (81 pages)	-19%
Century Gothic “Super Saving” (65.8 pages)	-34.2%

Table 4. Results of formatting changes on actual text with DejaVu font

Format (total page count)	% Reduction (from 100 pages)
Original (100 pages)	none
Deja Vu Original (100 pages)	none
"Page Saving" (66.1 pages)	33.9%
Deja Vu "Page Saving" (72.3 pages)	27.7%
"Super Saving" (51.6 pages)	48.4%
Deja Vu "Super Saving" (56.2 pages)	43.8%

From Tables 3 and 4 it can be seen that, while Century Gothic in conjunction with other typographic changes still results in a reduction of pages, it is only through these other changes and not related to Century Gothic. Century Gothic instead causes an increase in page length that the other typographic changes are counteracting to some degree. This finding indicates that Century Gothic, although potentially ink saving, is not a good choice for the final suggested format.

Average character width of a font is the main determinant of paper consumption, assuming other factors like type size are equal. A quick view of relative character widths and economy of fonts can be seen in Figure 1, which compares a representative nonsense keyword (Hamburgetfontiv) in the fonts tested in this study. Note that Déjà vu Sans Light Thesis is the same width as Arial Regular but lighter in weight, while Times New Roman is both narrower and lighter than Arial.

Hamburgetfontiv - DejaVu Sans Book
 Hamburgetfontiv - DejaVu Sans Light
 Hamburgetfontiv - DejaVu Sans Light Thesis
 Hamburgetfontiv - Arial Regular
 Hamburgetfontiv - Times New Roman

Figure 1. Visual font difference in width

Typography and Ink Use

Procedure

After it was determined that graduate theses would be the focus of the study, the choice of typeface as a means of saving printer ink was investigated. As seen in Table 1, two fonts were named as options: Times New Roman and Arial, with “unspecified” also occurring. Times New Roman (also called Times Roman) is a serifed typeface designed for *The Times* newspaper in 1931 (“Times Roman”, 2010), and Arial is a sans-serif “Grotesque” style typeface designed in the 1980s (“Arial”, 2010) as an equivalent to a well-known Swiss sans-serif typeface, Helvetica, designed in 1957. None of these typefaces were designed with the goal of ink savings. These font faces were compared to Century Gothic (“Century Gothic”, 2010), the geometric sans-serif that the press release from University of Wisconsin Green Bay indicated was more economical in ink consumption than Arial.

The estimated ink consumption was compared not by measuring actual ink used, which was impractical given the wide range of devices and image marking technologies, but by measuring the number of black pixels used to image each typeface at the same size, resolution, and text. In the Photoshop application, each typeface was set in a 600 dpi document at 72 points in the lower-case alphabet a–z. A histogram was calculated for each typeface to determine the number of black pixels used in the sample alphabet. By basing the measure of ink consumption on pixels in a digital image, the problem was abstracted from particular measures of ink-jet ink or laser-printer toner on various devices. While the abstract pixel measures do not give actual measurements of ink or toner consumption, they do provide a relative measure that is device-independent. The number of black pixels in each typeface is shown in Figure 2.

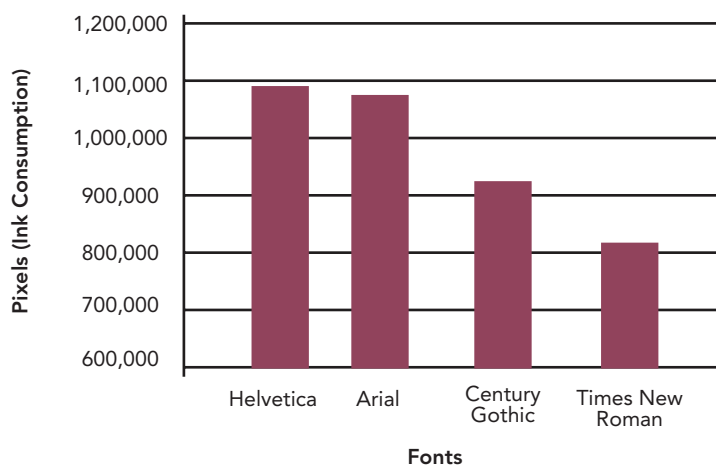


Figure 2. Font comparison

It is evident that Times New Roman saves the most ink—even more than Century Gothic, the typeface chosen by University of Wisconsin Green Bay. After analyzing these fonts, it was decided that, though Times New Roman saves the most ink, the research should investigate sans-serif fonts because of their contemporary popularity and connotations of a clean, technical look appropriate to an institute of technology. Additionally, sans-serif fonts are easier to modify because they have less visual data to accommodate than serifed fonts. Because Helvetica and Arial were the highest in ink consumption, the goal was to find a sans-serif design that would have a similar graphical look and connotation, yet use less ink. First, other fonts specifically created for ink saving were looked at, including EcoFont (Spranq – <http://www.ecofont.com>) and InkSaver (Scriptorium – <http://www.fontcraft.com>). Figures 3 and 4 show the printed version of letters e and r using the Spranq font at 8pt. Figures 5 and 6 show the printed version of letters e and r using the Ink Saver font at 8pt.



Figure 3. Spranq lowercase e



Figure 4. Spranq lowercase r



Figure 5. Ink Saver lowercase e



Figure 6. Ink Saver lowercase r

These fonts save on ink by placing holes or striations within the text, but user testing performed for this study suggested that both were objectionable in terms of congeniality (the pleasure of reading). That is, readers seemed to feel that the fonts looked “gray” or were inferior in image quality. A font of more traditional form was sought that could, if necessary, be modified to achieve ink savings.

It was observed that the major reason Arial consumes more ink than Times Roman is the heavier weight of Arial, which has thicker letter strokes and features than those of Times New Roman. Conversely, Century Gothic consumes less ink than Arial because its letter strokes are thinner than those of Arial. However, the set width of Century Gothic is wider than that of Arial, so a given amount of text will require more pages to set in Century Gothic than in Arial (if equivalent in size), though ink consumption would be less.

From these observations, it was surmised that a lighter weight of Arial could offer ink savings similar to those of Century Gothic, while consuming less paper than Century Gothic and without the loss of apparent quality caused by perforating the letter images with holes or stripes. There is, however, no lighter weight of Arial available for text composition, and the intellectual property rights of the developer of Arial would prohibit deriving and distributing a lighter weight of the typeface. Hence, an open-source typeface called DejaVu Sans was selected, and several experimental modifications were made for comparison with Arial, Times, and other typefaces.

Figure 7 shows the typefaces tested in the study. The chart shows the number of black pixels used for a fixed amount of text in each typeface.

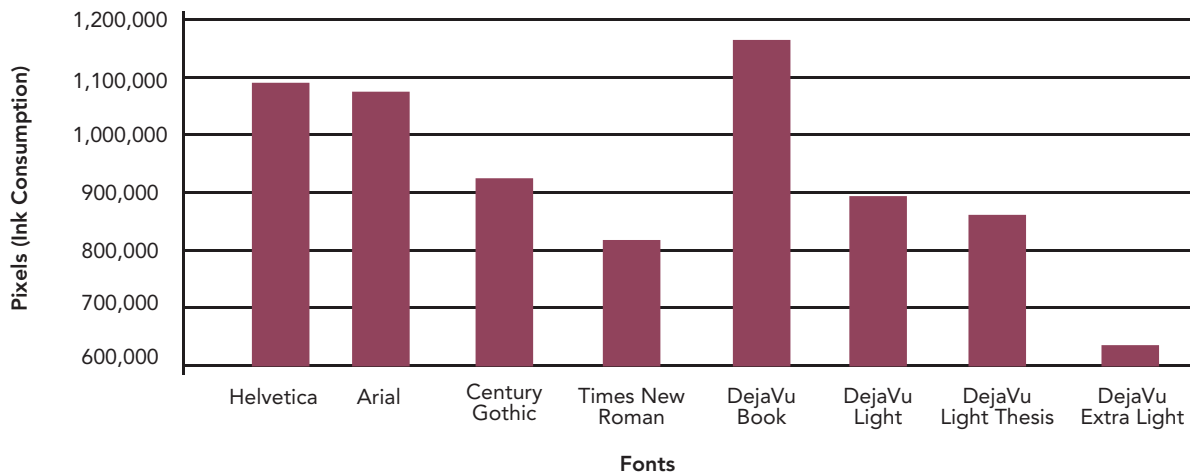


Figure 7. Eco-font comparison

Analysis of the font histograms in Photoshop showed that the first of the modified DejaVu faces, DejaVu Light, was markedly lower in ink consumption than Helvetica and Arial and slightly lower than Century Gothic. Next, DejaVu Light was modified to make it exactly metrically equivalent to Arial when set at the same point size. This resulted in slightly greater savings in ink consumption. This new version was labelled DejaVu Light Thesis.

Table 5 represents the amount of pixels saved when compared to Arial. This shows, in percentages, how much is saved when changing the typeface from DejaVu Sans Book, to

DejaVu Sans Light, to DejaVu Sans Light Thesis. DejaVu Sans Light Thesis saves a total of 19.34% when compared to Arial, nearly one-fifth of the total amount. Thus a typeface that provided a marked reduction in ink consumption was achieved while matching the paper consumption of Arial and remaining congenial in appearance to readers.

Table 5. Ink saved compared to Arial

Typeface	Pixels	% Saved compared to Arial
Arial Regular	1,071,130	none
Deja Vu Sans Book	1,164,699	none
Deja Vu Sans Light	894,124	16.53%
Deja Vu Sans Light Thesis	863,994	19.34%

Font Modification

DejaVu is a typeface that was developed by Bitstream in 2004 and released as an open source font (<http://www.dejavu-fonts.org>). It since has been expanded to include a sans serif family (in a number of weights) and a serif family (also in a number of weights). Both the working font files and outlines are available as a free download, and the designs may be modified and redistributed. DejaVu is often distributed with Linux as a default sans-serif font and includes a very large character set for multiple languages and mathematical expressions. This open source typeface was selected so that modifications could be freely made and the modified fonts redistributed for free.

The DejaVu Sans family includes book, bold, and extra light weights. The book weight is lighter than Arial but still heavier than desired for ink savings. The extra light weight is too thin to be readable over hundreds of pages. FontLab Studio, a professional type design software (<http://www.fontlab.com/font-editor/fontlab-studio/>), was used to interpolate a new intermediate weight. Interpolation takes the two existing font files and creates a new set of letter outlines that are somewhere in between the two. A 50% interpolation between the book and extra light weight was made. This provided greater ink savings while maintaining readability.

In order to increase compatibility with current thesis documents, the widths of the interpolated weight, called DejaVu Sans Light, were modified to match the widths of Arial. The resulting font, DejaVu Sans Light Thesis, allows users to switch a document from Arial without compromising page and line breaks. In order to match the widths, however, the outlines of most characters had to be modified. Without modifications some characters would appear darker or unevenly spaced, hindering the readability.

The open source nature of the DejaVu family allows distribution of the modified font freely. RIT can offer DejaVu Sans Light Thesis on a web server so that students can download and use it for their thesis documents. Theoretically, the font could be included in future releases of DejaVu Sans as well.

Conclusions

Measurement of ink and paper consumed in the printing of documents must take into account not only font choices but also their spacing and arrangement within the defined parameters and pragmatic goals of specified documents. The typefaces and document layouts common in academic printing were not designed with the goal of reducing ink and paper consumption, but moderate changes in typographic format and fonts can result in substantial savings in ink and paper. Compared to thesis composition in Arial, the use of Times New Roman or a modified DejaVu Sans font can result in savings of ink from 19-25%. Compared to typical RIT thesis guidelines, thesis formats designed for economy can result in paper savings of 27-48%. When dealing with students whose average page consumption numbers in the thousands, such as the graduate students at RIT, a reduction of even 27% (about 270 pages out of 1,000) can be a huge savings.

Future Research

Anecdotal evidence suggested that the modifications in document formats and fonts did not appreciably reduce document readability or congeniality, but these factors should be investigated more rigorously. The goal of printing is, after all, communication, so modifications made to increase sustainability must not decrease readability or congeniality if printed communication is to remain effective. Another area of future research would be to determine the ink consumption and composition economy of additional typefaces and fonts and to make additional experimental modifications of fonts to achieve greater ink savings.

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