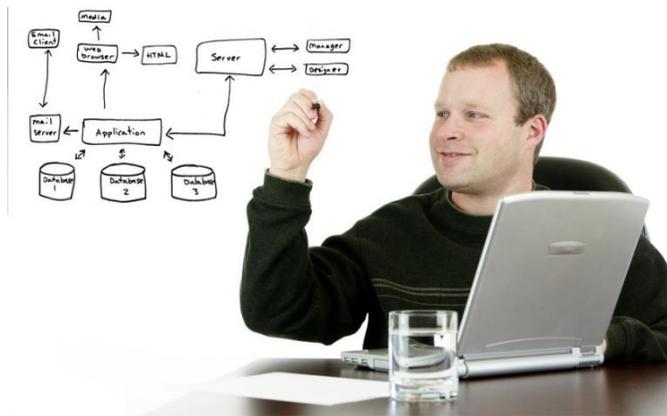
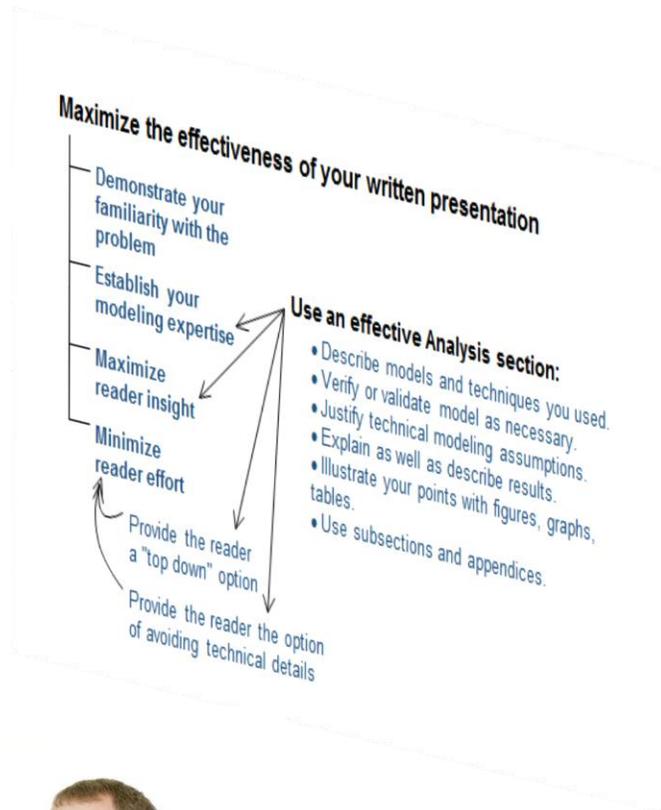


WRITING EFFECTIVE PROJECT REPORTS



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SUMMARY

This document presents strategies you can use to write an effective project report, and prescribes an organizational structure for writing such a report. Four fundamental objectives for writing an effective project report are cited, namely, demonstrate your familiarity with the problem, establish your modeling expertise, maximize reader insight, and minimize reader effort. Writing strategies and organizational structure are meant to secure these objectives. You are expected to be aware of the material in this document and implement it in an appropriate manner when writing assigned project reports.

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INTRODUCTION

You are a member of a project team assigned to review fuel procurement policies for an electric utility. Or perhaps your task is to investigate the feasibility of integrating automated bar-coding schemes into the production and shipping facilities of an automotive supplier. Or possibly you are a student dealing with these problems as part of a case project assignment. You have a real or hypothetical client who must make a decision based on your recommendation. The client may be your superior and hence internal to your organization, or you may be employed by a consulting firm working for an external client. Or you may have an instructor who must evaluate your project work. Your team has investigated the problem, performed an analysis and must communicate its recommendations by writing a project report. How should you go about composing this report?

In what follows, I present guidelines, recommendations and strategies for writing project reports of this type. These strategies are based on an assumption of *pure self-interest* for you or your project team – you want to do the best you can to preserve or enhance your standing in your organization and to further your career goals. One of the best ways to accomplish this is to *establish your competence* with the client or your instructor. That is, you want to instill confidence in your analysis, results and recommendations, *and* instill confidence in your own capabilities, both in problem-solving and in presenting your case. You want to maximize the effectiveness of your written presentation in achieving these objectives.

Your Goals In Writing A Project Report

Figure 1 presents an objectives hierarchy for writing a project report. The hierarchy divides the overall objective of maximizing the effectiveness of your written presentation into four sub-objectives. The first two sub-objectives, demonstrating familiarity with the problem and establishing modeling expertise, help establish your competence. These two sub-objectives relate to the *substance* of your report. If you do not achieve these, then your recommendations will not be convincing, regardless of how polished your written presentation is.

The third sub-objective is maximizing reader insight. You can achieve this by judiciously drawing attention to intuitive aspects of the problem on which your results crucially depend, or by emphasizing parts of your analysis which explain simply what should be done or why. It is very important to *explain* and not merely *describe* your results. If the substance of your report is solid but the client gains no insight into his problem by reading your report, then the client is much less likely to implement your recommendations.

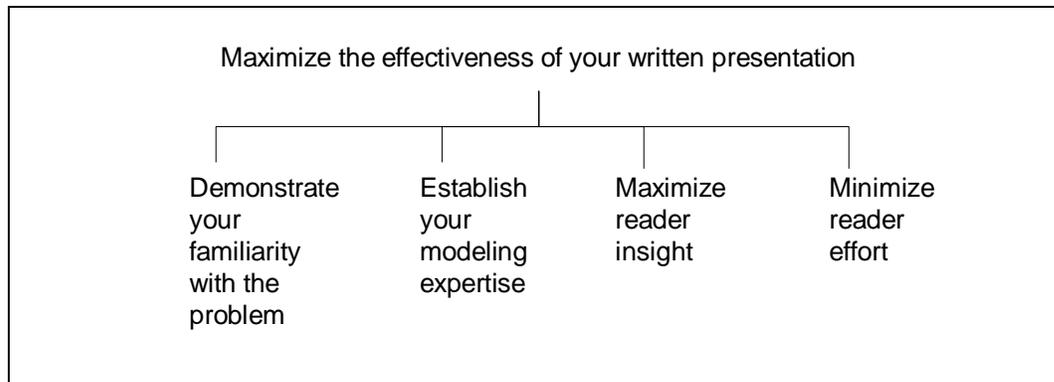


Figure 1: An objectives hierarchy for writing a project report. The overall objective of maximizing effectiveness of your written presentation can be divided into the four sub-objectives indicated.

The fourth sub-objective is minimizing reader effort. Clients are busy people. If you do not provide the client with easy and quick ways to learn the gist of what you have done, then the client is much less likely to read your report, and much less likely to understand what he/she has read. Your instructor may have to read 20 reports like yours in a few days. If s/he cannot understand what you have written without expending more time than s/he wants, your grade will justifiably suffer. All of the advice given below regarding the *organization* of your report and *proper writing style* to use has as its objective to minimize reader effort.

You can save your reader work at the organizational level of your report or at the sentence level, as Figure 2 indicates. The general strategy for minimizing effort at the sentence level can be simply summed up: Avoid forcing the reader to repeatedly read text for understanding. I will elaborate on this below.

The sections below discuss three general strategies for minimizing reader effort at the organizational level.

- Your reader needs to *get to the point* of your report quickly, and a properly organized report should facilitate this.
- Your reader should be able to follow your document’s structure from the top down. *Almost no one will want to read your report through from first page to last in a linear fashion.* Your reader should be able to proceed “top down”, by selecting only parts of your report to read in detail while still understanding the purpose and context of other parts to which he/she gives less attention.
- Your reader should be able to choose the level of technical detail he/she wishes to read. A properly organized report will give him/her the option of avoiding technical detail should he/she desire.

All of these objectives and strategies will be further discussed in the sections which follow.

One of the most frustrating project reports I have ever graded was written by a student who had decided to try to convey the *complete experience* he and his teammates had in tackling their assigned case. Beginning at the beginning, he described every step, every

mistake, every backtrack and every partial success. The document structure consisted of little beyond “First we did this, Next we did this, Next”. I therefore had no *top-down option*, and I was forced to read his story from beginning to end, which was the last thing I had the time or patience for. I wanted him to give me insight, but spare me the effort of learning how he came by that insight. I wanted to *get to the point*, but could not do so by reading his report. The strategies described below are meant to keep you from following in his footsteps!

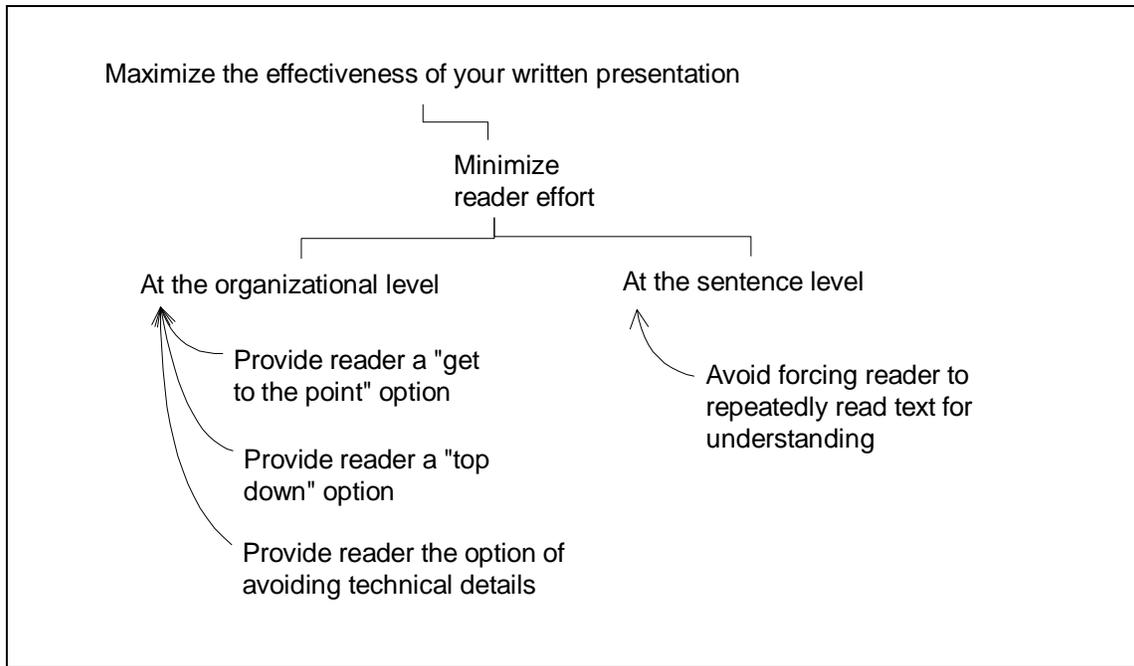


Figure 2: Strategies for minimizing reader effort can be directed at the organizational level of the report or the sentence level. We will cover three general strategies at the organizational level and one general strategy at the sentence level.

STRUCTURING YOUR DOCUMENT EFFECTIVELY

The document structure we have recommended for project reports in this course consists of the following, arranged in the order indicated:

- A title page
- A Summary
- A Table of Contents (optional for very short reports)
- An Introduction section
- An Analysis section, optionally divided into subsections
- A Conclusions and Recommendations section
- A References section (optional)

- One or more Appendix sections (optional)

Please create these sections, in this order, unless you have compelling reasons to revise the list. Each element of this structure will serve one or more of your goals in its own particular way, as we will discuss below. However, as Figure 3 emphasizes, the overall purpose of establishing this kind of document structure is to *provide the reader a get-to-the-point option, as well as a top-down option*. A reader wishing to get the gist of your report can peruse your section headings to see in broad outline what you have done. He or she may then skip over certain sections or subsections and focus on others.

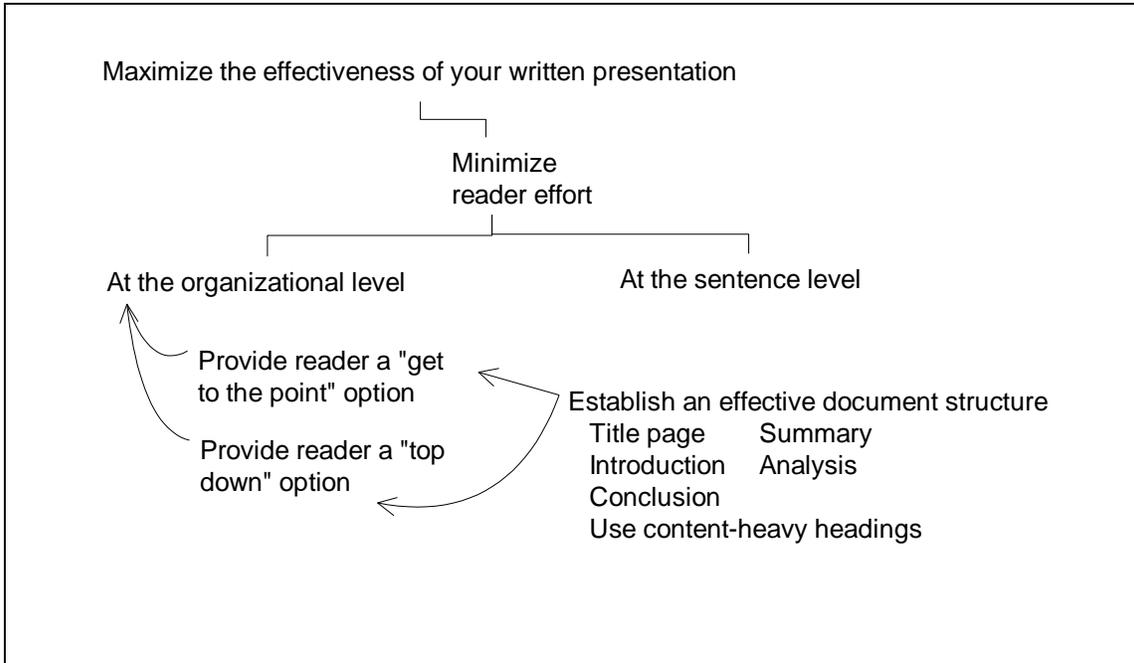


Figure 3: Establish an effective document structure by using a title page and a Summary, creating Introduction, Analysis and Conclusions sections, and using subsections freely with content-heavy headings. The goals served by establishing an effective document structure are to provide the reader a "get to the point" option and a "top down" option.

Use Content-Heavy Headings

The purpose of document structure is to provide your reader with “top down” and “get to the point” options. These options can only be realized, however, if your section and subsection headings convey content meaningfully. You should strive to achieve this. It is literally true that the best section headings make it *less* likely that your reader will need to read the section. Here are some examples.

| Poor | Good |
|---------------------|--|
| Proprietary Tempers | Meeting the Demand for Proprietary Tempers |
| Hearth Utilization | Optimizing Hearth Utilization |
| Introduction | Introduction: Incentives for Optimizing Inventory |
| Analysis | Using Auger Electron Spectroscopy to Characterize Corrosion Products |

Figure 4: Using content-heavy headings can convey meaningful content to your reader. This helps give your readers “top down” and “get to the point” options.

Your Title Page

The standard form we have used for a title page is displayed in Figure 5. It is fine to make up a name for your project team, as was done in the example in the figure. If you are composing the title page, make sure you get your teammates' names right!

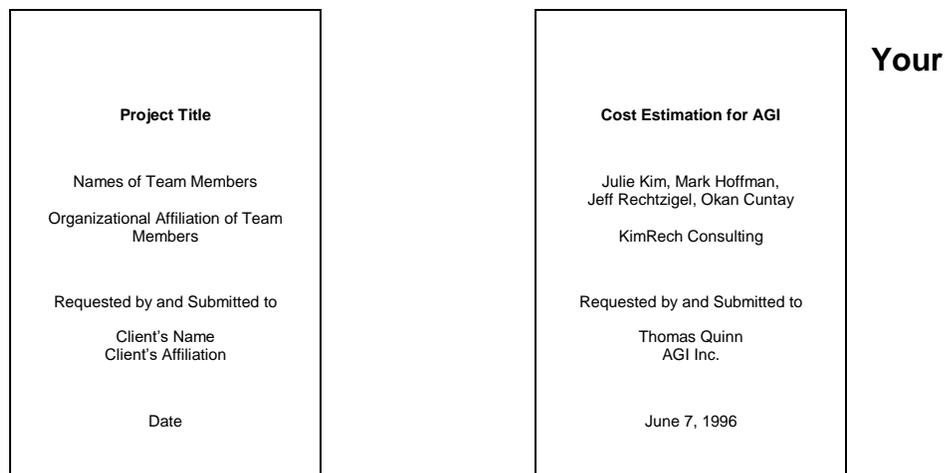


Figure 5: The generic form for a title page on the left, and an example title page on the right.

Summary

The Summary follows the title page and appears on a separate page of its own. At a minimum, your Summary should be a *self-contained* document in which you

- briefly state the problem, and
- summarize the important conclusions of the study

It is important to note that the abstract is self-contained, that is, it stands by itself independent of the rest of your paper or proposal. Although it must describe what is going on in your report, it should not refer the reader to any particular section, figure, table, or equation in your report. Conversely, even though the summary comes first, the discussion in your paper cannot use or refer to information from the summary unless this

information has already been introduced in the paper. Your paper and its summary stand as two independent documents.

Depending on the context of the study, it may make sense to include additional information in your summary, such as:

- what brought about this particular study,
- who the client is,
- what the objectives of the study were,
- what assumptions or restrictions were imposed
- what actions the study recommends

The precise content may vary, but *the key is to include the minimum amount of information that it takes to communicate the essential message of the report.* A very good summary might be sufficient to give some readers an adequate understanding of the report even before reading it.

It is always best to keep the summary to one page or less (*much less*, if possible). Remember who will be the audience for the report; do not include unnecessary introductory or background material that the readers do not need. *Get to the essentials, fast!* Assume the reader is busy and will give the Summary only a minute or two of attention; use short lists (as above) to call out key points. The purpose of the summary is to give the reader a “get to the point” option, as is summarized in Figure 6.

Write your summary last, to ensure that it reflects your completed thinking about the problem, your analysis, and your presentation. If you write the Summary first, it tends to come out sounding like an Introduction – which belongs in the main report.

Put some work into making your Summary read well. It is the first (and often the only) part of the report that people read, so you want it to make a good impression.

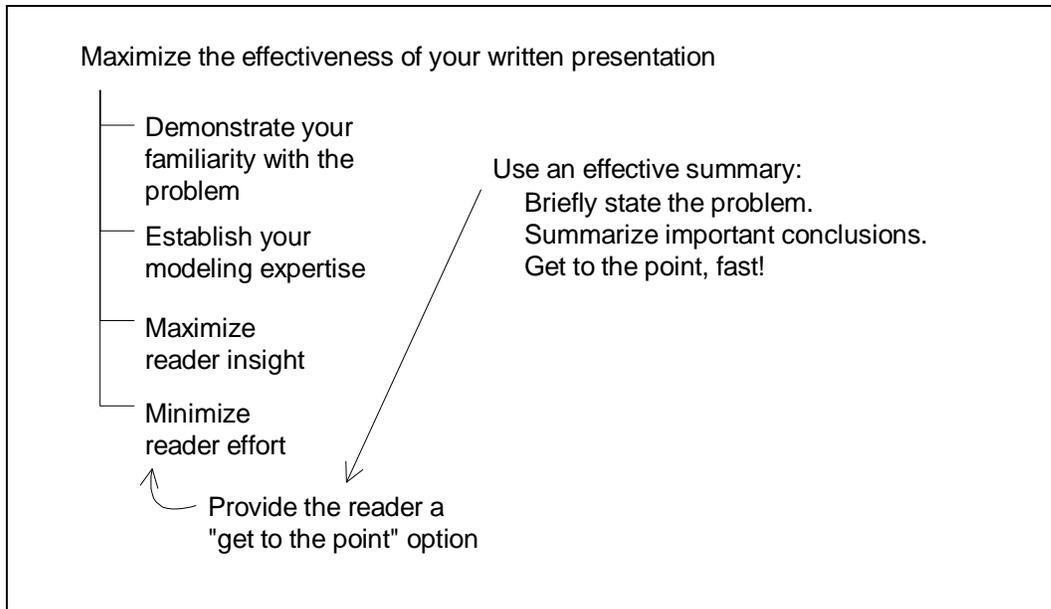


Figure 6: An effective summary includes the minimum amount of information that it takes to communicate the essential message of the report.

Your Introduction

In this section – which can also be titled “Background” or “Project Statement” – you should include:

- Relevant history, such as how this project came about, who sponsored it, and background details about the client organization that are germane to the project.
- A precise statement of the problem, including any restrictions or assumptions that were imposed on the project by the sponsor.
- An overview of the purpose and scope of the study, which gives the specific objective of the study and any major assumptions or constraints that were imposed by your project team.

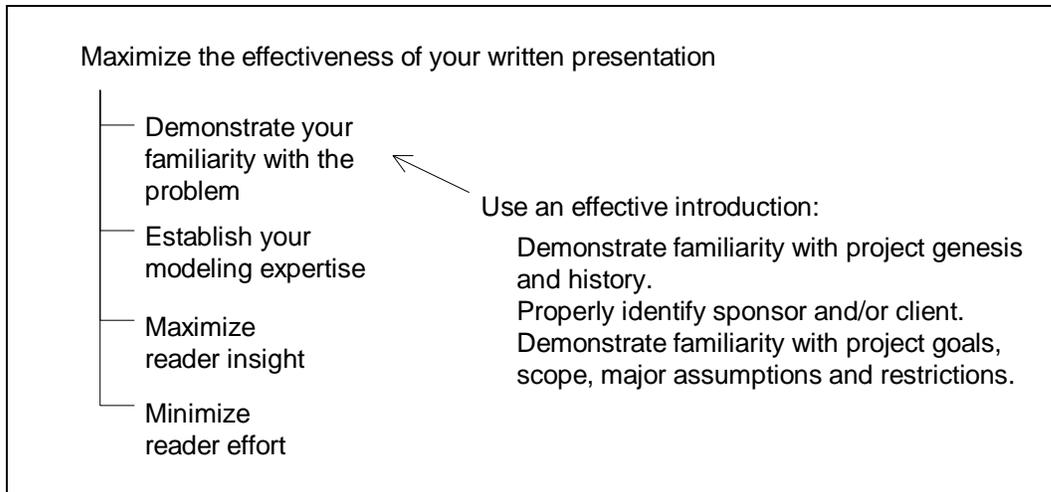


Figure 7: An effective Introduction demonstrates your familiarity with the problem.

Your Analysis Section

This section explains how you applied techniques of Industrial Engineering and Management Science to the problem at hand. An effective Analysis section should establish your modeling expertise, while maximizing reader insight and minimizing reader effort. (Figure 8). Included in your discussion should be:

- A careful description of models and techniques that you employed.
- Details of modeling assumptions or constraints that you imposed in order to make your analysis possible.
- A description of whatever data inputs your model required, how you estimated parameter values from data, and where your data came from.
- A description and explanation of the results of the analysis.
- A discussion of whatever verification, validation or sensitivity analysis has been done for the model and results.

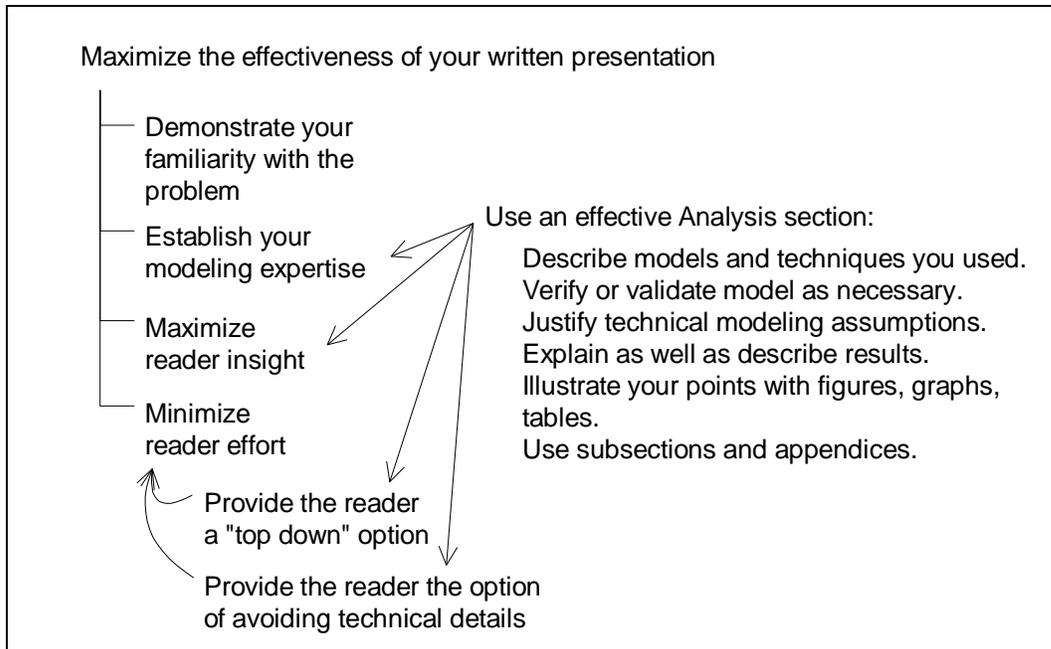


Figure 8: An effective Analysis section helps establish your modeling expertise, maximizes reader insight, and provides the reader a “top down” option and the option of avoiding technical details.

Notice that this section is concerned with *modeling* assumptions that you imposed for *technical* reasons. For example, you might assume that machine failures are exponentially distributed so that you could use a certain convenient formula for expected downtime; then you would verify that data for actual machine failures conforms reasonably well to an exponential distribution. On the other hand, any *major* assumption imposed for *nontechnical* reasons, such as restriction of the analysis to the most costly production line because your time is limited, should be stated in the Introduction.

The discussion in this section should be detailed enough to enable the knowledgeable reader to duplicate your analysis. The presentation should be purposeful, however; *go only into those technical details that are directly relevant to what you have done* (minimize reader effort). Naturally, you will want to present your work in a positive light, emphasizing the power and appropriateness of your techniques (establish your modeling expertise). However, it is equally important to be honest in your descriptions; you should make all your assumptions clear, and mention any significant limitations to your approach (maximize reader insight). If you expected your analysis to yield particular results, describe them, and then contrast your results with your expectations.

Use figures, tables, graphs and appendices

In describing the results of your analysis, you should aim for a comfortable balance between numbers and words. Numerical data – such as the results of a simulation or optimization run – should be summarized in tables, graphs or figures that are carefully designed to present the information clearly. The text should explain the data in broader terms, citing particular numbers only for emphasis. Again, the goal is to maximize reader insight and minimize reader effort.

If your analysis is particularly technical, you may have a lot of mathematical formulas and numerical tables that you want to provide to the client. To keep the Analysis section readable, it is often a good idea to relegate this material to appendices; see the further discussion of appendix sections below. This strategy minimizes reader effort by giving the reader a “top down” option and the option of avoiding technical details.

Use subsections

Even with details relegated to an appendix, the Analysis section is likely to be the longest part of the report. To help the reader follow it, you will do well to organize it into subsections. Commonly used subsections include

Model Description
Assumptions and Justification
Data Collection
Parameter Estimation
Solution Approaches
Results
Sensitivity Analysis

and so forth – but these are only examples, and you may use some or none of these, or whatever is appropriate to your particular situation. If your analysis is especially lengthy or complex, you may break it into two or three natural parts and devote a whole section to each part. Again, the goal is to give the reader a “top down” option and the option of avoiding technical details.

Explain as well as describe

To increase reader insight, it is particularly important to *explain* results rather than merely describe them. For example, you may have formulated an optimization model to solve a facility location problem. If the model objective is to minimize total costs, you should not merely describe the optimal solution and its cost, but also give some intuitive justification for the optimality of this site. For instance, site A might be best in spite of its greater distance to key markets because of lower labor costs in its region.

Your Conclusion and Recommendations Section

This section can be titled “Conclusions” or “Recommendations” or both, depending on the nature of the report. In it, you give the implications of your study for the actual system at hand. You need to include the following items:

- A list and discussion of your specific conclusions – paralleling the list you gave in the Summary, but with more detail.
- An explanation – in words – of how your analysis supports your conclusions.
- Recommendations for putting your conclusions into practice in the client’s real system.
- A discussion of “human factors” considerations – the implications of people’s needs and preferences for the implementation of your recommendations.

- Suggestions for further analysis.

Take extra time to make this section readable. Next to the Summary, it is the section most likely to be seen. The presence of a concluding section gives readers a “get to the point” option: *Some readers will skim through the report to get to your conclusions, so be sure that this section does not require too much familiarity with the Analysis section to be understood.*

Almost always, a single study is not the last word on a problem. While you should try to make your conclusions specific enough to be useful, do not oversell your analysis. If important questions remain, say so, and try to indicate how they might be attacked. Try to suggest further work that you feel is most relevant to the current project and that can be most strongly justified; a long laundry list of vaguely defined future projects will not have as much credibility.

Often in the assigned cases for this course, your task will be to recommend a general procedure for a firm's recurring problem. Usually in such cases a specific instance of the problem will be cited and data will be given for that instance. Many teams have felt that they ought to confine their discussion of a proposed general procedure to the Recommendations and Conclusions section, and use the Analysis section for the specific instance of the problem. *However, it is not a good idea to wait until the final section of your report before you say anything at all about the primary problem you were tasked to examine!* You can propose general policy (maybe even more than one) and evaluate it (them) in the Analysis section – don’t wait until the final summarizing section of your report to discuss general policy if in fact it is general policy you were asked to address.

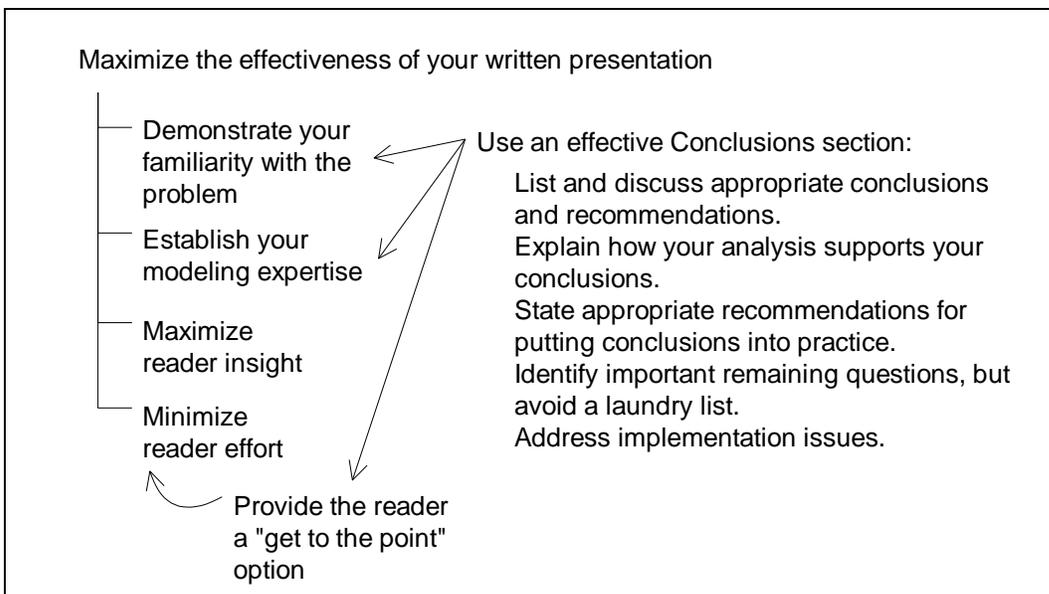


Figure 9: An effective Conclusions section gives the reader a “get to the point” option, and reinforces your modeling expertise and image of competence.

EFFECTIVE ELEMENTS YOU MIGHT USE

Using a Table of Contents

The primary purpose of a table of contents is to minimize reader effort by giving him or her a “top down” option: The reader can consult the table of contents to get an overview of what you have written, or to orient himself while reading your report, or to identify sections to focus on or skip. This assumes that you have given *meaningful and descriptive* titles to your sections and subsections. For short reports (4 pages or fewer), the reader can achieve these objectives by simply scanning your section headings, so a table of contents need not be included. For longer reports with more than a few sections or subsections, you may find it worthwhile to use the automatic table of contents generators available in some word processing packages. Page numbers in your document should begin with the Introduction page numbered 1.

Using Lists

Use lists to call out key points you wish to emphasize, or to break up a sequence of items which would be cluttered or hard to access visually in a paragraph format. Because lists force your statements into a parallel format, the differences between items stand out more clearly. A reader can select items to focus on, or can approach listed items looking for contrasts. Lists give the reader a “top down” option, so he or she may scan the listed items repeatedly, focus on some and give minimal attention to others. Lists can be used in every section of the report. This document contains many examples of the use of lists.

Identify items in a list with bullets rather than numbers unless you wish to quickly refer to those items subsequently, or unless you want to emphasize their ordering (as with steps in an algorithm).

Structuring Paragraphs and Sections “Top Down”

It is impractical to provide a heading for every paragraph you write – unfortunately so, because this would give your reader another “top down” option. However, you can accomplish the next best thing by structuring your paragraphs “top down”. You do this by beginning your paragraph with a sentence or sentences that summarize what you plan to say. Subsequent sentences flesh out and provide details. For instance:

To maintain our “preferred-vendor” status, the board voted positively on two key issues: to realign departments and to continue the current hiring trend. The realignment will occur this spring, as described in Attachment 4. New personnel will include sales and marketing staff, technical consultants, IT specialists, and support staff. Requests from these departments have priority during this next hiring phase. ...

Here we have underlined the initial summarizing sentence.

Fortunately, sections and subsections have titles that can be made content heavy, giving the reader another top-down option, as we have already mentioned (p. 4). However, in many cases, there is only enough room in a section title to hint at the section contents, and almost never enough room to explain *why* the section is

important or why the reader should bother to look at it in detail. However, you can accomplish these tasks in the opening paragraph of the section, by briefly summarizing what the section contains, why you are presenting the material you do, why the material is significant, and/or how the material relates to other parts of your report. Doing so gives the reader both “top down” and “get to the point” options. Many of the sections in this document begin in this way.

Using Figures, Graphs and Tables

Figures (including graphs) and tables are among the most powerful tools you have for summarizing and conveying insight into your analysis and numerical results. They should be used in the Analysis section or its appendices. Graphs and charts are particularly useful because they can visually emphasize trends or comparisons which are hard to otherwise detect. Graphs and figures can be used to summarize key technical details which are otherwise too lengthy or cumbersome to be presented. A basic convention is that a figure or table should stand by itself and should not be part of the text flow – rather the reader’s attention should be drawn to it by an explicit reference in the text.

Figures or tables just a few lines high can simply be centered on a page with adequate space above and below. Larger figures (including graphs) and tables should be numbered consecutively and placed at the top or bottom of a page (or a separate page if they are really large). Each should have a caption of the form “Figure n:” or “Table n:” followed by a text description of the figure or table. This document contains examples of larger figures. Figure captions appear below figures, and table captions appear above tables.

In graphs and charts the axes should have, to the degree that space allows, content-heavy labels; and in tables, the row and column titles should also be content-heavy, again to the degree that space allows.

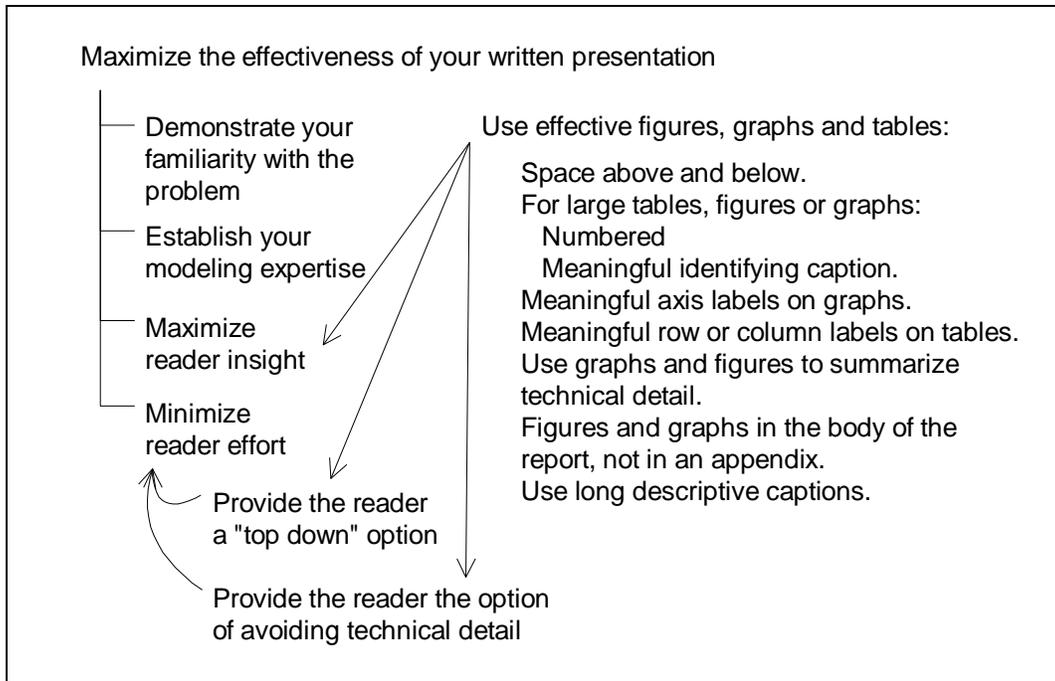


Figure 10: The effective use of figures, tables and graphs can greatly increase reader insight and help minimize reader effort. A sequence of figures with long descriptive captions (such as this one) can provide the reader with a top-down option for traversing your document.

Using long descriptive captions

One effective strategy for minimizing reader effort consists in designing figures with descriptive captions one to several sentences in length – that is, by using content-heavy captions. By perusing a properly designed sequence of figures, the reader can let the figures “tell the story” of your report’s contents and results. In fact, the figures in this document have been designed in this way. This "long caption" strategy therefore supplies the reader with another top-down option. The journal *Interfaces* and the popular magazine *Scientific American* use figures in this manner. Figure 11 shows an example of this strategy in an article from *American Scientist*.

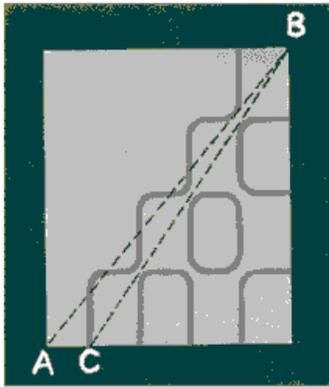


Figure 9. "Gerrymandering" problem arises from the fact that nodal domains are not localized to small regions of the membrane. Here, narrow necks create a connected nodal domain whose diameter, BC, is virtually as large as the diameter of the entire membrane, AB.

from physics and geometry. Two frequencies can coincide exactly, as in the example we saw earlier, only when two different pairs of integers (say n_1, m_1 , and n_2, m_2) satisfy the equation

$$a^2 = a^2 n_1^2 + m_1^2 = a^2 n_2^2 + m_2^2$$

This can happen only if a^2 is a quotient

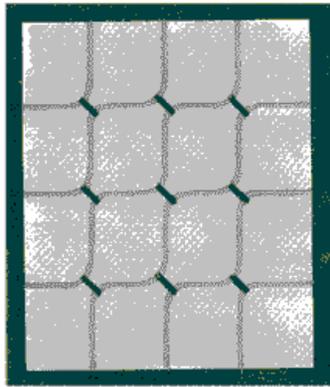


Figure 10. Author's solution to 'gerrymandering' is to cut the nodal domains across the narrow necks. Each cut region is treated as a new nodal domain. The lowest fundamental frequency is worked out for each cut region, and this information is used to reconstruct the density.

became evident to us that this was not enough to solve the interference problem, because the nodal patterns of two different natural frequencies could interfere even if the frequencies were very close, but not identical, to each other. Thus we needed a^2 not only to be irrational, but also to be not very close

expansion (for example, 3.14159 is a rational number). More subtly, a number like π may be approximated by fractions, such as $22/7$ ($= 3.1428 \dots$) or $355/113$ ($= 3.1415929 \dots$), an approximation known to the ancient Chinese. We can always get better approximations by taking fractions with a larger denominator, but we can consider an approximation to be "unreasonably close" if it is much closer than the size of the denominator would warrant. Both of the above approximations to π could be considered "unreasonably close," which is why they were known and used centuries before the irrationality of π was fully understood.

In essence, then, we need the shape constant a^2 to be an irrational number with few "unreasonably close" rational approximations. Rather miraculously, number theorists know that the vast majority of irrational numbers satisfy our criteria (although no one knows whether π does!), and hence it is not a severe restriction on the shape of our membrane. The one price we pay is that we still have to ignore a few "bad" natural frequencies. The theorem from number theory does not allow us to eliminate the interference problem altogether, but it does allow us to assert that the number of frequencies where

Figure 11: The use of long descriptive captions in the July-August 1998 issue of *American Scientist*. Notice how the authors' Figure 9 poses a problem and their Figure 10 then describes the solution. You can obtain a good idea of the contents of their article by simply looking at the figures and reading the captions.

Do not appendicize graphs and diagrams

Because the software you may use to generate a graph or diagram is often different from the word processing software you use to compose the report, you may find it tempting to print the graphs and diagrams and physically attach them to your report in an appendix. Although this strategy may be convenient for you, it only increases the amount of effort expended by your reader, who must search for the graph or diagram in the appendix when it is mentioned, and then jump back and forth between it and your text, possibly losing his/her place in the process. Worse, the reader may not even take the trouble to find your graph or diagram, thereby bypassing any insight you intended to provide.

There are exceptions to this rule. For example you may feel it natural to accompany a statistical analysis with a plot or histogram, but feel that only the conclusion of the analysis belongs in the main part of your report. It would then be appropriate to put the details of the analysis into an appendix along with the plot or histogram.

Embedding charts or diagrams into text documents is not difficult with today's software. Microsoft Word has a drawing toolbar which can be used to construct diagrams. Graphs produced by spreadsheet programs such as Excel can be easily copied and pasted into documents produced by Word or WordPerfect. Indeed, most graphics software allows this option. Moreover, hard-copy pictures or diagrams can be scanned and inserted into

documents. For example, the figures in this document were produced by embedding Visio diagrams into a Microsoft Word document, or in the case of Figure 11, by inserting a scanned image.

Using Appendices

In reports that have a substantial technical component, it is often a good idea to include one or more appendices. Again, this strategy minimizes reader effort by providing a top-down strategy and allowing him/her to avoid technical detail should he/she desire. Items that go into an appendix include:

- *Background material and data.* Examples include excerpts from previous studies, data previously collected by the client, and architectural drawings
- *Computer input or output.* A computer program or your input to a simulation or optimization package may be listed, as well as the output from such packages. However, if these are very long, they should be included on a disk instead.
- *Raw data.* You may wish to provide detailed tables or graphs showing the numbers that you summarized in the Analysis section of the report.
- *Derivation of analytical expressions.* If you took an expression from a book or article, simply citing it is enough; but if you derived the expression and it is not obvious, you should give the derivation in an appendix.
- *Tedious calculations.* You may not want to interrupt the readers train of thought by including, say, the details of a long present-value computation. Instead, simply say “the present value of Alternative 3 is \$352,000 (see Appendix A for details)” and let the interested reader consult the appendix for the complications involving taxes, depreciation and the like.

In general, material that *enhances, summarizes, or helps illustrate the discussion* in the main body of the report *should in fact be in the main body of the report*. If you want the main body of the report only to mention that something was done and not discuss the details, then the details can go into the appendix. This is why figures should in general not be put into an appendix – they typically help illustrate the main body discussion.

If you have several of these items to include, put each in a separate appendix. Identify the appendices by letters A, B, C, and so forth.

Using References and Citations

A References section is not always necessary, but should be included if you cite results from books or articles. In the main text of your report, you should cite your sources in a uniform way, and in the references section, your list of references should have a uniform style. In one style, book titles may be bolded, journal articles italicized and authors names listed "last,-first". In another style, book titles might be italic, journal articles quoted, and authors names listed first-last. You can adopt any style as long as you use it consistently. There are style books in all libraries, and on the internet, but you can also adopt a style from a textbook or article. Most journals have an Instructions to

Contributors section which appears annually, in which citation and reference style for that journal are described. Appendix 1 contains examples of citation and reference styles. If you use one your readers are more likely to have seen, your style will seem invisible to them.

WRITING EFFECTIVELY AT THE SENTENCE LEVEL

The entire goal of writing is to produce clear text with unambiguous meaning. Contrary to popular belief, it is not an easy task.

Your writing should be free of mistakes in spelling, punctuation and grammar. Blatant mistakes jar your reader out of your report to think about you – in unflattering terms. More subtle mistakes work against you more subtly – by forcing your reader to expend more effort just to understand what you meant to say (Figure 12). Good spelling, punctuation and grammar are not important in themselves. When they serve your purpose of communicating clearly the substance of your report, they are invisible.

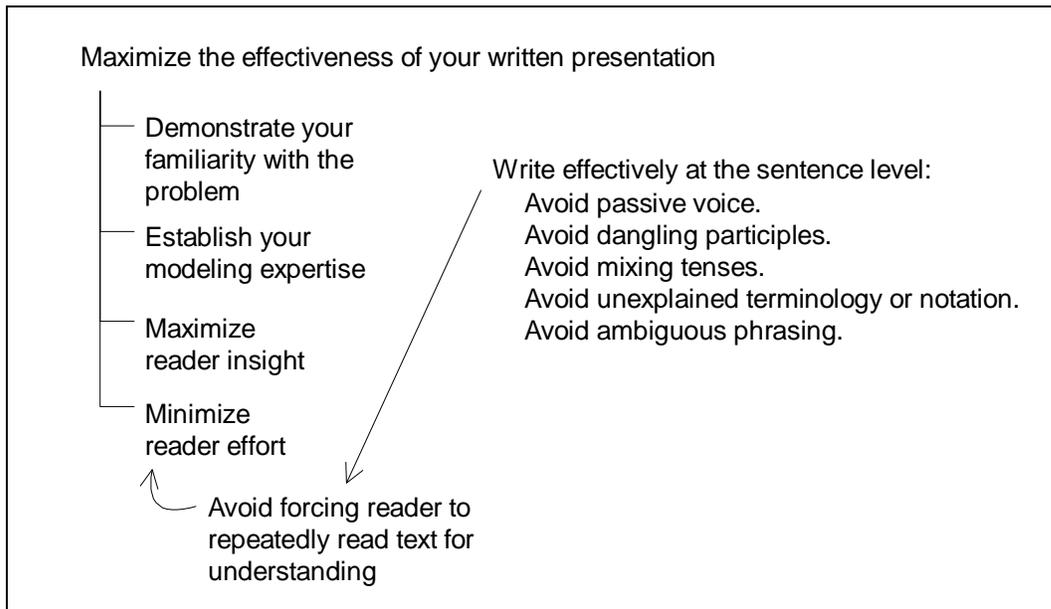


Figure 12: The primary purpose of writing well at the sentence level is to minimize reader effort by not forcing him/her to repeatedly read text for understanding.

Avoid the passive voice

The active voice – “X did Y” – is usually preferable to the passive voice – “Y was done by X” or “Y was done.” The latter form of the passive (where you omit the agent X) is particularly dangerous because it results in ambiguity concerning the agent’s identity. In a consulting environment, both you and your client may perform actions, and sloppy use of the passive voice may obscure who is acting. For example, consider the following sentences from a hypothetical project report:

On the first day of our trip, the assembly floor was visited to collect time-study data. Initially, molds were placed on a conveyor belt followed by a retail box.

Ambiguities abound here. Did we visit the assembly floor, or was it the client? Did we place the molds on the conveyor, or do assembly floor workers do this routinely? Does the retail box follow the conveyor belt or follow the molds? Use of the active voice can remove these ambiguities:

On the first day of its trip, our team visited the assembly floor to collect time-study data. Workers routinely place molds and then a retail box onto a conveyor belt.

The passive voice is particularly likely to creep into lists or headings from which you have omitted the agent for brevity's sake. The passive voice is often essential for lists and headings, but if you must use it, try to use the form "Y was done by X" in which the agent is identified. Suppose, for example, that in a client's quality control procedure, a quality control officer (QC) rejects or accepts a lot of manufactured items prior to shipping by counting defects in a sample taken from the lot. To evaluate this procedure, your team has done a full count of the defects in both accepted and rejected lots. In your report you might present several tables, including the table depicted in Figure 13.

| | Lots Rejected | Lots Accepted |
|--------------------------|------------------|------------------|
| Average Sample Size | 23.3 | 30.4 |
| Average Defects Found | 3.37 | 1.57 |

Figure 13: A table with headings in the passive voice and agents not identified. Who is rejecting and accepting? Who is finding defects? The reader cannot tell.

Most probably the phrase "Average Defects Found" refers to the average number of defects *your team* found. However, it might also refer to the average number of defects the *QC officer* found in the sample on which he based his accept/reject decision. Perhaps the distinction is clear in the discussion surrounding the table, but a reader who glances through your figures and tables to get the gist of your results would miss your discussion. Similar ambiguity could arise over the phrase "Average Sample Size." This must refer to the average sample size used by the QC officer, because your team did not take a sample. However, a reader performing a quick scan of your report would not be aware of this. It is better to remove the ambiguity by restoring the agents to the table. This is illustrated in Figure 14.

| | Among Lots the QC Officer | |
|---------------------------------|---------------------------|----------|
| | Rejected | Accepted |
| Average Sample Size QC used | 23.3 | 30.4 |
| Average No. of Defects We Found | 3.37 | 1.57 |

Figure 14: The same table with agents identified. Aha! It is the quality control officer (QC) who is accepting and rejecting. We are finding defects.

Avoid dangling participles

Participles are verb forms which serve as adjectives. A *dangling* participle occurs when the noun modified by the participle is missing or misplaced. A few examples, in which the dangling participles have been italicized:

Having been tested, drivers transport the donated blood to Richmond for distribution.

Lying unconscious on the street, an ambulance was rushed to the scene.

Assuming independent observations, the data was sorted into low, medium and high categories.

Dangling participles create ambiguity if the reader cannot identify the modified noun. In the first sentence above, are the drivers tested (as the sentence seems to say) or is it the blood? In this case it is in fact the blood which was tested, and the sentence becomes an unintended joke. The same effect occurs in the second sentence, where presumably the ambulance cannot lie unconscious on the street. The third sentence, however, seems to work, even though we know that data cannot make assumptions. These sentences can be rephrased to remove the problems:

Having been tested, the blood is transported to Richmond for distribution.

The injured lay unconscious on the street , and an ambulance was rushed to the scene.

Assuming independent observations, we sorted the data into low, medium and high categories.

In sum, dangling participles may create ambiguity (thereby forcing the reader to re-read text for meaning) or expose your writing to ridicule (thereby undermining your competence). Don't use them.

Other sources of ambiguity

Don't mix tenses in one paragraph.

Mixing tenses can create ambiguity and should be avoided:

We developed a system of standards to be used in quoting jobs. In order to validate these standards, we consult recorded data. Predicted completion times were compared to actual times and found to be reasonably similar.

The verb tense shifts from past in the first sentences to present in the second sentence to past in the third sentence. The reader is left to wonder whether recorded data was consulted once (as the writer intended to say) or several times on a continuing basis as the standards evolved (as the present tense might imply).

Don't mix groups and individuals in one paragraph, either.

At any one moment, you can talk about "the workers" or "a worker", but when you use a pronoun to refer back to that noun, remember that if you said "workers", it must be "they" and if you said "worker" it must be "he" (or "she"). If you need to use one alternative for emphasis, recast the rest of that paragraph to use the same reference. And, of course, verbs must agree in number with their subjects.

Avoid using words new to your client.

Unusual or novel terminology should be explained when you introduce it. If at all possible, use your client's terminology. For example, writing "bill-of-materials" when the client uses "schedule-of-materials" can create ambiguity and undermine your image of competence by giving the impression you are uninformed.

PROOF YOUR DOCUMENT FOR ORGANIZATION AND CLARITY

Textual ambiguity can arise in many other ways. For example, as I composed this document, I originally gave the section in which I discussed writing a Summary the title "Summary". I realized, however, that you the reader might then interpret this section as *being* a Summary section, rather than *being about* the Summary section. Therefore I re-titled it "Your Summary", and followed suite with "Your Introduction", "Your Analysis Section", and so on.

Because you as the writer will have greater background knowledge than your reader concerning your project analysis, phrasing which baffles your reader may seem completely clear to you. In effect you are too close to your topic to see it through your reader's eyes.

Here are some things you can do – after writing – to improve your report's organization and clarity:

- Proof your document. Take the time to make this a serious step. Do it with a skeptical eye, searching for alternate interpretations which might confuse someone less informed than you.
- Lay your document aside and return to it when its details are less fresh in your mind.

- Ask a team member not involved in your part of the analysis to read what you have written. Ask her to be critical. Listen hard (even watch, if you can) to catch where she gets puzzled. Don't answer her questions, but make her show you why she asked them.
- Pretend you are a client in a hurry who is reading your document for the first time. Read only the title page, the Summary and the Conclusion. Can you figure out what the gist of the report is? Glance through the figures and graphs and read their captions. Are they understandable by themselves?

Your goal is text which flows smoothly and creates little ambiguity, as well as a top-down organizational structure which lets the reader get to the point. The overall goals are to minimize reader effort and maximize reader insight.

CONCLUSION

In this document I have discussed strategies you can use to achieve your goal of writing an effective project report. Although this document is not itself a project report, you can mimic it when you compose the reports you will be assigned in this course. However, use caution and common sense – I would not, for example, expect your reports to be as long as this document. In your analysis section, you will use graphs and tables in addition to figures, and you will likely use appendices as well.

When I grade your project reports, I will expect you to be aware of the contents of this document and make a reasonable attempt to follow its advice and warnings. It may be worthwhile to take another look at the big picture provided in Figure 1. Of the four goals listed there, I as a reader of your report would most strongly emphasize *minimizing reader effort*. In Figure 2, I would emphasize minimizing reader effort *at the organizational level*, and in particular, *providing a get-to-the-point option* and *providing a top-down option*. Pay particular attention to the advice given in this document which relates to these objectives. In particular, good document structure and the effective use of subsections can be very helpful. In my experience, the single most overlooked strategy is the use of figures, graphs and tables *with long descriptive captions* (Figure 11). You should not underestimate the power of long descriptive captions to give a reader a quick overview of what you have done.

Acknowledgements

A substantial portion of this document was drawn from the document *Writing Project Reports*, composed in 1992 by Professors Robert H. Fourer and Wallace J. Hopp of Northwestern's IEMS department. I also am grateful for the comments and suggestions of Marilyn Justman of *JustWrite Consulting*, as well as insights provided by Mary Ryba Knepper and Roger Rueff of Ryba Associates, Inc.

APPENDIX 1: REFERENCE STYLES

Whatever reference style you decide to use, you should stick with it consistently throughout your report. Below I quote the style instructions for several popular professional journals. Any of these would be acceptable for references in your report.

Operations Research

List only those references that are cited in the text. References in the text should be cited by the author's surname and the year of publication - for example, Flood (1962). If the reference has two or three authors, cite all of the authors' surnames and the year of publication - Flood, Smith and Jones (1982). If the reference has more than three authors, cite the first author's surname followed by et al. and the year of publication - Brown et al. (1985). If there is more than one reference by the same author with the same year of publication, the first citation appearing in the text would read Flood (1962a), the second citation would read Flood (1962b), etc. Do not use parentheses or brackets for dates when the citation is already enclosed within parentheses (for example: Flood 1962).

At the end of the paper list references alphabetically by the last name of the first author. Do not number the reference list. Double space this final section. For journal references, give the author, year of publication, title, journal name, volume, and pages – for example:

FLOOD, M. M. 1962. New Operations Research Potentials. *Opns. Res.* 10, 423-436.

For book references, give the author, year of publication, title, publisher, city, state, and pages - for example:

MORSE, P. M., AND G. E. KIMBALL. 1951. *Methods of Operations Research*. John Wiley, New York, 44-65.

For references to working papers or dissertations cite the author, title, type of document, department, university, and location, for example:

ROSENWEIN, M. 1986. Design and Application of Solution Methodologies to Optimize Problems in Transportation Logistics. Ph.D. Dissertation. Department of Decision Sciences, University of Pennsylvania, Philadelphia.

Interfaces

Cite references in the body of the text: ". . . Thrump [1978] quibbled that . . ." or if 1978 was a prolific year for Thrump, "[1978b]." If the author is not cited in the text, then use [Thrump 1978]. Alphabetize the list of references according to the name of the first author. For articles use the form

Smith, James Q. 1978, "Title of article," *INTERFACES*, Vol. 10, No. 5 (September-October), pp. 45-50.

and for books:

Toklas, Alice B. 1947, *BOOK TITLE*, Publisher's name, City, State (or Country).

and for collections of papers:

Beedle, Albert A. 1979, "Title of chapter," in BOOK TITLE, ed. J.J. Fox, Publisher's name, City, State (or Country), pp. 556-572.

Avoid references to your own publications; you may use the same ideas again without fear of plagiarism. Refer to your previous publications only if the current subject absolutely requires it.

Organization Science

All references cited in text are to be listed alphabetically by author at end of paper and should be double-spaced. References should begin on a separate page headed "References" and should be in the following format:

Colombo, R. A. and D. G. Morrison (1989), "A Brand Switching Model with Implications for Marketing Strategies," *Marketing Science*, 8, 1.

Massy, W. F., D. B. Montgomery and D. G. Morrison (1970), *Stochastic Models of Buying Behavior*. Cambridge, MA: The MIT Press.

Citations of references should be designated throughout text by enclosing author(s) name(s) and/or year of reference in parentheses. Tables and figures should be numbered consecutively, typed on separate pages and grouped together following references section. Use of tables should be designed to complement presentation in text. Position of tables and figures should be indicated in text. Footnotes and references to unpublished papers should be avoided. Footnotes, if required, are to be listed numerically at end of paper as endnotes and should begin on a separate page.

Transportation Science

References in the text should be cited by the author's surname and the year of publication, e.g.: (Jansson, 1980),(Marguier and Ceder, 1984).

The following format should be used for references:

Journals:

W.B. POWELL AND I.A. KOSKOSIDIS, "Shipment Routing Algorithms with Tree Constraints", *Transportation Science* 26, 230-245 (1992).

Working papers and dissertations:

B. GAVISH AND S.C. GRAVES, "Scheduling and Routing in Transportation and Distribution Systems: Formulations and New Relaxations", Working Paper 8202, Graduate School of Management, University of Rochester (1981).

Books:

I. PRIGOGINE AND R. HERMAN, *Kinetic Theory of Vehicular Traffic*, Elsevier, New York (1971).