The following pages were supplied by Richard de Neufville, based upon the materials used in his thesis proposal class.

An important resource that **all** TPP students should be aware of is the MIT Writing and Communication Center - 14N-317.

There is an online guide to the Center:

- The MIT Online Writing and Communication Center Site Index: http://web.mit.edu/writing/site_index.html

The Center describes itself as follows:

> The Writing and Communication Center offers free services to all members of the MIT community during the academic year. It is located in the building 14N-317, the same building as the Hayden Library. Every year hundreds of MIT undergraduate and graduate students, staff and faculty members, spouses and alumni/ae come to the Center for individual consultations about any writing difficulty, from questions about grammar to matters of style. Native speakers and non-native speakers of English visit the Center regularly. Some professors ask their best writers to come to the Center to fine-tune their style or organization skills.
>
> Whatever your skill level or confidence level, the Center can help you improve your skills as a writer and speaker.

Before contacting the Center, please read their online guide to make sure you will get the most of their services.

F. Field; March 2002

THESIS DEFINITION AND PREPARATION
SOME GENERAL GUIDELINES

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PREFACE

A thesis can be one of the most rewarding, productive experiences of a graduate student's career. As an educational venture it is fundamentally different from the normal classroom experience. It is an opportunity for students to be creative, to bring together and integrate skills they have acquired, to make a real professional contribution. The thesis is a means for students to demonstrate both to themselves and the world that they have achieved a respectable level of professional maturity.

Doing a thesis is also a rare opportunity for a person to concentrate intensely on a professional project they care about, and which they have defined. Many will not have similar experiences again for a long time, if ever. Work after graduation is often spread out over many different projects, and subjected to all kinds of extraneous pressures. The period in which you do your thesis is – whatever it may seem like at the time – relatively sheltered and unpressured. You should appreciate it.

A thesis is often scary. No doubt about it. Many students are initially anxious about how they will manage to complete such a large and demanding project, generally much larger and more challenging than anything they have previously done professionally. Moreover, many naturally suffer from moments of despair along the way as things do not go according to plan. This is natural too.

Many of these thesis crises can be prevented or overcome by appropriate forethought. With the proper guidance, much of the possible pain of doing a thesis can be avoided.

This manual presents some guidelines designed to help students execute their thesis expeditiously. These represent both philosophical and practical suggestions concerning issues which have appeared most troublesome to students. They get revised regularly based on comments and suggestions – yours would be most welcome.

Experience validates the usefulness of these guidelines, especially to students who have some latitude in defining their thesis topic. Over 700 graduate students in the MIT Technology and Policy Program have tested these recommendations since 1980.

Experience also indicates that students doing a thesis benefit from carrying out the exercises at the end of each chapter. These explicit exercises represent tasks that all thesis students should in any case be doing, implicitly in their heads if not on paper. They are thus definitely not a waste of time. They provide opportunities for the thesis student and the advisor to check progress on the thesis and to make mid-course corrections in good time.

1. THESIS FORMULATION

The Issue

Most students find it difficult to formulate their research. This is an ordinary phenomenon resulting from the nature of the venture.

This comment deserves emphasis because thesis students in the process of defining their research tend to blame themselves for their apparent lack of progress, and to become discouraged. This negative experience can, however, be avoided by understanding and adopting the right attitude toward the process, and by taking appropriate steps to formulate the thesis. This chapter is designed to help you define your research with a minimum of difficulty.

Formulation of a thesis is inherently challenging because it is research, because it is an exploration into the unknown. Serious research implies a substantial commitment of effort to an activity whose end product is quite uncertain. People would be strange indeed if they did not wonder whether it is worthwhile to invest themselves on some topic whose final value is unclear. Lack of motivation is thus an essential problem.

Just as students cannot anticipate the results of research, they also find it difficult to define the methods and data they should use in the investigation. There is a close relationship between the means of research and the ends to be accomplished, between the choice of method and data and the kinds of results that can be obtained. For example, a statistical analysis of a series of data inherently generates a description or understanding of average, aggregate behavior; a case study on the other hand can illuminate detailed patterns of cause and effect, but does not easily lead to general results. The most appropriate choice of research method depends on the kinds of results you propose to obtain. When possible results are unclear, it can be difficult to choose the right method.

Much of the agony of thesis formulation can be avoided by developing a clearer idea of what you should be looking for: What is a thesis, in fact? What are its essential elements: How does one formulate research properly?

What is a Thesis?

There is much misunderstanding about he meaning of a thesis. The problem stems from the fact that the objective reality of the form of a thesis – a long document with specific features (abstract, conclusions, bibliography, etc.) – does not define the intellectual significance of the work. This difference between form and substance is confusing. Some people act as if they believe that meeting the

superficial attributes of a thesis (length, etc.) will produce a satisfactory thesis. This is not the case, however. There are several classes of professional documents – such as consulting reports – which can have the exterior aspects of a thesis but not the substance. What then is a thesis?

A dictionary definition of a thesis provides a good initial answer. According to Webster's New Collegiate, for example: A thesis is "a proposition that a person advances and offers to maintain by argument".

This definition has three key elements.
1. A thesis is a *proposition*; it advances an idea, a hypothesis or a recommendation;
2. A thesis offers an *argument*, it presents a rationale for accepting the proposition made rather than simply asserting a point of view; and
3. The argument of the thesis should be *maintained*, should be made convincingly by appropriate logic and sufficient evidence.

An alternate definition of a thesis is provided by suggesting what is not a thesis. A chronology or other description of a situation is not by itself a thesis (nor is it good history). A straight analysis, for example a large statistical study, is also not a thesis. Nor is an essay expressing a point of view or an opinion. Each of these materials can, of course, be important parts of a thesis if properly used to advance and defend an argument.

In short, a good thesis makes a point. It suggests an answer to some issue or question. It attempts to validate that answer.

Essential Elements

The formulation of a research project, a thesis in particular, should thus address four issues:
- What is the *question* or issue?
- What *method* will be used to address this questions?
- What *evidence* can be applied?
- What *logic* integrates the above?

A Question

A thesis is helpfully framed as a question that defines the issue under consideration. You may think of it as a hypothesis. For example, the proposition that mediation is a better way to resolve disputes than litigation can be put as a question: "Is mediation a better way to resolve disputes than litigation?"

The idea that a thesis revolves around a question – first put and then answered – must be stressed. Most thesis students do not understand this at first. Their

ideas about long reports typically are based on term papers rather than research. They thus tend to define their thesis in terms of a topic instead of a question. For example, when asked to define their thesis they usually give answers such as: “Development of Cable Communications,” “Pricing of Electricity,” “Materials Selection in the Automobile Industry,” etc. Understandably, the normal first step is to work in an area that interests you. However, the topic does not by itself define a thesis. In each case you need to identify a specific research question within the context of the topic.

The research question must certainly have more than one possible answer. If it cannot be refuted it is a truism of no real interest. For example, the hypothesis “Can Systems Dynamics be Applied to Sustainable Development?” seems to have only one answer, yes. It is hard to see how Systems Dynamics could not be applied somehow. A more challenging hypothesis might be “Is Systems Dynamics more Effective than Macroeconomic Modeling for the Analysis of Sustainable Development? “ The answer to this question might be either yes or no, and the research could lead to a surprise, a new insight. This could be worthwhile and interesting.

An Interesting Question

The topic should be worthwhile. You invest considerable effort in your thesis: make it count.

The question you chose for a thesis should be intrinsically interesting. In defining your thesis ask yourself if the answer to the question has some potential for making a difference. Try to identify what that difference might be, and use this to judge the merit of the thesis.

The question should be interesting to others, at least to some specific audience. From the start, you should anticipate how your effort might help you gain some recognition. Identify the people who would care about the results of your work – and whom you wish to impress. Define their concerns and the problems they feel should be solved. Ask yourself how your thesis could really be of interest to the audience you wish to address.

The question should certainly be interesting to you. If it is not, you will have difficulty sustaining the motivation necessary to get the work done in a reasonable time.

An Appropriate Method

It is essential to select a research procedure that can lead to answers to the questions you set for yourself. This should be obvious.

Judging by what many student researchers do, however, the need to select a research method appropriate to the question is not obvious in fact. People often study an issue with some method (a statistical analysis, a case study, an optimization) for tangential reasons. They may be skilled at the method, have convenient computer programs available, or simply fall into it. These factors are not sufficient reasons to select research methods. The critical factor is whether or not your research tools will do the job.

The consequence of not selecting the appropriate method is a lot of work with little significance; the question really is not answered. Avoid the law of the hammer. Just because you have a specific tool available, do not think it fits all problems. Just because you have a hammer in your hand, do not think you are dealing with a nail. It may be a screw.

The process of selecting a research method should focus on the kinds of result each approach can provide, and then address the issue of whether these results could in fact answer the question as posed. If they cannot, then either the research method or the question should be altered. Which should be changed depends upon your preferences; the important thing is that method and question be compatible.

Incompatibility between question and method arises frequently when people do a focused study of a particular situation. For example, a student may wish to work on the general question of what the optimum pricing strategy for an industry should be, by studying the experience in the home country or a particular company. Such case studies are systematically unsuited to general questions. It is logically unacceptable to base general propositions on an anecdotal observation of a particular situation. Either the scope of the analysis must be expanded to more cases, or the question must be limited to the specific situation.

It is important to understand that many interesting questions do not translate into good research questions or thesis subjects, for the simple reason that no available method is appropriate for answering the question. For example, the question of whether God exists is interesting to many people, but quite inappropriate for research since there is no method of providing answers to the question. It is a pity that you must exclude many worthwhile questions from your list of thesis topics simply because you will not be able to answer them. Yet you had better face this reality when formulating a thesis rather than later, when you find that you are wasting your effort.

In thinking about your method, it helps to be specific. Defining your method in general terms such as “Optimization” or “statistical analysis” does not identify enough specifics so that you can estimate either the potential results of the method or its usefulness for your situation. When you think of your method specifically, for example as “linear programming” or “t-test analysis,” then you

can define the potential result you could get, the kind of data you require, and generally whether the method is suitable for your question.

It is equally essential to select a method that is within your reach. Do you know, or can you learn soon enough, how to carry it out? Will you have the resources – in laboratory supplies, computer time and programs, travel money, etc. – to do so? Before you commit yourself to a specific method, be sure you are confident you will be able to use it successfully.

Evidence

To argue your thesis convincingly, you need to back your assertions with relevant facts. Right from the start you should determine if these are really likely to be available.

Be skeptical about the availability of data. Evidence is often much more difficult to obtain than initial optimism may suggest. As Chapters 4, 5, and 6 indicate, collecting data is generally expensive in terms of money, time and effort.

You may expect many obstacles in gathering evidence. Institutions are typically reluctant to release data. Facts embody some measure of power or advantage: they may help the competition, they may embarrass someone. Many agencies or companies are thus slow to release complete sets of information.

Be wary of uncertain prospects. As an advisor I am always somewhat worried by the following kinds of assertions.

- "The ABC company (agency) is starting something new and I will be able to share their data" – maybe, assuming that the project actually gets going well before the thesis is due – which many do not;
- "I have contacts at ABC, and they have promised to let me see their files" – one student who told me this had to wait an extra year to get to see the data, and then only in a limited censored version that was virtually useless.

Adopt a fail-safe strategy. It is always best to be sure that the minimum evidence you require already exists or is within your control to obtain. Problems in completing a thesis due to lack of appropriate data are a reflection of a poor thesis formulation. Problems with the availability of data are not a valid excuse for a poor thesis.

Logic

Finally you need to integrate your method and the evidence logically, so that these together constitute a sound logical means to argue your hypothesis.

Ask yourself first of all: What are your criteria for success in establishing your hypothesis? By what measures will you know that you have answered your questions successfully? Then ask yourself what kind of results are in fact likely to emerge from applying your method to the evidence available? Will these results likely be sufficient to make your point? If not, you need to revise either your question or the method, to make them logically compatible. Chapter 8 discusses in detail some ideas about how you may construct a good logical argument and support the point you wish to make in your thesis.

Remember that your logic needs to convince others. The logic used must therefore be adjusted to the audience. For example, if you are trying to make a case for the deregulation of the telephone system, you will need to make a different argument to legislators concerned with the impact of changes, than to economists who already are convinced of the benefits of free markets. Your logic needs to address and surmount the difficulties your audience will have in accepting your results.

Critical Experiments

Research formulated around a "critical experiment" is often particularly effective. For the students, a critical experiment is especially desirable since it leads to a good thesis regardless of how the results turn out. This is because the results will validate one or another of several theories or models.

A critical experiment is one that helps decide between two (or more) competing theories on a subject. The concept is as follows. In general there are many theories about or models about how a system behaves. People rarely totally agree on how to explain any set of phenomena or observations. All significant theories will account for the major, obvious characteristics of the subject – otherwise they would not be serious contenders. The several competitive models will differ however, in that they lead, in some way, to different implications about some particular details. A critical experiment is one that investigates such details to see what happens: depending on the result one (or more) theories are validated (or at least appear more likely) and the others are refuted (to some extent).

Critical experiments are often particularly interesting because the results can be decisive for the validity of competitive theories. They thus tend to attract a lot of attention, which is almost always good for the thesis student or researcher.

To formulate a thesis around critical experiments and evidence, it is necessary to develop a good understanding of the models that are used in an area. This leads to the appreciation of how they differ and what is required to distinguish between

them. A thorough, thoughtful literature search, as suggested in Chapter 4, is particularly essential to formulate incisive research questions.

Guidelines for Thesis Formulation

The fundamental guideline is that every person formulating a research or thesis topic should consider question, method, evidence and logic simultaneously. These four should all be compatible and feasible. If they are not, the formulation is defective and probably inappropriate. The basic checklist in Exhibit 1.1 provides specific guidance concerning what you need to do to formulate your thesis. It has proven useful for a number of people. Hopefully it will for you too.

Exhibit 1.1: **Basic Checklist for Formulation of a Research Topic**

1. *Question*

- Do you have a hypothesis, a question, or a point to be made about an issue? Note that this is different from a general topic.
- Is this hypothesis refutable? Does your question potentially have different answers?
- Who might be interested in the answer to the question?
- How does this potential audience now understand the issue?
- How does your question address their concerns?
- Are you yourself interested in the question?

2. *Method*

- What is the proposed method, specifically?
- Do you already know how to apply this method?
- Do you have the resources to apply this method (the time to learn it, the equipment or program to carry it out, the money to pay for it?

3. *Evidence*

- What kind of data does your method and question require?
- How much of it do you already have in hand?
- How sure are you that you will be able to obtain what you require within your deadline? What obstacles might prevent you from obtaining what you need?
- Will you have a "fail-safe" plan, so that you can complete the work even if you do not get the data you want?

4. *Logic*

- What logic will you use to argue your hypothesis?
- What kind of results do you expect to get from applying your method to the evidence?
- What does your audience currently know or believe? What logic will it take to take them from where they are now, to the message you want to leave them with?

2. ABSTRACT

An abstract is a short account of the key elements of a thesis, professional paper or report. Its principal purpose is to communicate rapidly the significance of a particular effort.

An abstract is generally easiest to write when the report is done. Then you know what you have accomplished, and what you can summarize.

It is a good discipline, however, to write abstracts both at the beginning and during the progress of the research. You ought to be able to describe to yourself where you are going, how you propose to get there, and why this accomplishment is worthwhile. To the extent you cannot, your research is out of control. That is not a good situation to be in on a major project like a thesis. This observation motivates the discussion of abstracts at the beginning of these guidelines for research.

Length

The length of an abstract should not exceed 200 or 300 words, *maximum.* Professional media are ordinarily quite strict about the length of the abstract, and you should get in practice. The rationale for the limitation in length is that the abstract loses its purpose if it is too long. Readers scanning dozens of abstracts to find a publication that will interest them are reluctant to read something more than a paragraph or so.

Even the most important discovery can be summarized in relatively few words. Anyone having difficulty doing so has not really focused on the important portions of their work. Knowing what your essential contributions are is the key to writing a good abstract.

Title

The title of the work is always associated with an abstract and should be considered an integral part of it. As the abstract itself, the title is part of your means of communication to potential readers.

The title of a professional report should refer to its key ideas. The title is most useful when it contains the keywords by which you want people to think about your work. Readers often decide whether or not to read an abstract simply by looking at the title. Librarians certainly catalog works largely on the basis of titles. If you provide an inappropriate title you will lose a portion of your potential audience.

Titles that do not describe the subject should be left to literary efforts such as fiction and poetry. Particularly avoid clever titles that amuse you – but confuse the reader. For example, consider the thesis titled "Enlightened Tunnel Visions": what is it about? New discoveries in ophthalmology? Plans for developing mining machines? Some kind of religious experience? Actually it was an excellent analysis of a system of one-way tolls for the tunnels under Boston harbor – but how would you have guessed? Ambiguities and opaqueness of this type should be avoided. When writing professionally, your objective should be to inform the reader.

Content

After the title has defined the subject matter, the abstract covers the rest of the information required of the summary. This includes:

- The point made by the thesis;
- The method used;
- The evidence presented, together with a brief description of how it was collected;
- The results obtained;
- The conclusions and recommendation; and
- Any special circumstances about the research.

The abstract in Exhibit 2.1 illustrates these guidelines.

Exhibit 2.1: **Example of a Reasonable Abstract**

Airport Privatisation or Corporatisation? lessons from the British Airports Authority Plc and Recommendations for Kenya Airports Authority

by Philip Wambugu

Many governments, airport owners/managers, and international bodies agree that airports should be run as economic entities. However, there is little agreement on the structure of the ownership/management for airports to accomplish this goal. Some see privatisation as the only hope for the economic rehabilitation of major airports, others prefer the status quo, yet others prefer joint private sector/government ownership or other hybrid solutions. To complicate matters, a policy success in one country may not translate to a similar success in a different country or time. Hence, world governments disagree on which policies to adopt for their airports.

This thesis evaluates the experiences of the successful British Airports Authority plc (BAA) of the United Kingdom; evaluates privatisation and corporatisation policy for Kenyan Airports; and makes recommendations for the administration of the Kenyan Airports using BAA as the reference case and experiences elsewhere, where the question of airport ownership and management is undergoing a metamorphosis.

The main lesson is that BAA's success seems more rooted in the changed operating environment after its corporatisation. In other words, my analysis concludes that privatisation of BAA did not lead to appreciable improvements in its performance. Value based pricing, investment projects, commercially aligned management and clear customer service concerns are striking similarities between the corporatised and the privatised BAA.

Thus for Kenya, corporatisation of airports is recommended considering the difficulties of implementing privatisation in Kenya. This has already been done. However, in addition, the introduction of commercialism in the airports body, strengthening of the manpower base with trained and capable staff, better planning and investment strategies, customer service concerns and freedom on pricing are recommended.

Conversely, Exhibit 2.2 provides an example of a less successful abstract. To see this, ask yourself: what does it really tell you? In this case that someone did a case study about switches that raised issues. Do you now know what the point of the thesis was? Is it, for example to list the issues? To show some generality across areas of high tech trade? That this case is on the contrary different in that it broke new ground? And what method or evidence was used? Is this an econometric study? A case of technology transfer? A political description? The abstract as written leaves too much unclear or unspecified.

Exhibit 2.2: **Example of a Less Successful Abstract**

The Case of Telecommunications in US Technology Transfer to China

The US and the People's Republic of China have been brought into a closer relationship by a convergence of economic and political forces. Technology transfer from the US to China is an important part of this relationship, serving US economic needs and aiding China's modernization effort.

While both sides benefit from the transfer, domestic and international export controls prevent China's access to the highest levels of our technology. Domestic division exists over whether to increase trade with China or to embargo

the 'critical' technologies. International division exists among the allies who disapprove of the US liberalizing trade with China while calling for tighter restrictions on exports to the Soviet Union.

To highlight the issues posed by high technology trade, trading with China, domestic and international export controls, a case study was used. The case involves the sale of ITT digital transit switches to the Chinese government in July of 1983. This case broke new ground in President Reagan's China policy and it was also the test case for stored program control TDMA digital transit switches.

Writing

Remember the basic rules for writing well:

- Each paragraph should express one main idea - not several;
- Each paragraph should have a front or "lead" sentence that expresses the main idea of the paragraph. A reader should be able to understand the essence of the text simply by reading the first sentence of each paragraph;
- Second and subsequent sentences should develop the idea presented in the "lead sentence."
- The final sentence in the paragraph should bring the idea to a close.

Further guidelines about writing can be found in:

- Amis, Kingsley (1997) *The King's English*: *A Guide to Modern English*, "A Harper Collins, London, England.
- Fowler, H. W. (1926) *A Dictionary of Modern English Usage*, Clarendon Press, Oxford, England.
- Strunck, W. (1927) *The Elements of Style* (revision, an introduction and a chapter on writing by E. B. White), 3rd. ed., Macmillan, New York, NY.

3. TIME BUDGETING AS AN ELEMENT OF RESEARCH DESIGN

The basic issue is that students writing theses often fail to anticipate the time required to complete their work. They share this problem with many researchers. Students, however, are especially vulnerable because graduation, jobs, vacations and other ambitions depend on finishing the thesis on time.

The pathology becomes apparent when the student realizes towards the expected date of completion that it will be extraordinarily difficult to get the thesis written and approved on time. In the first phase of the syndrome, the student turns into a haggard zombie working desperately round the clock. In the second phase – which afflicts a distressing number of thesis students – one observes canceled graduations, embarrassing inabilities to take up employment at the time promised, substantial added costs of tuition, etc.

These ills are all largely avoidable. The student needs to confront the realities of time budgeting right from the start of the thesis enterprise. The purpose of this chapter is to help you do just that.

More Work Than You Think

A first major error researchers typically commit, concerning time, is to be unrealistic about the total effort required. It is not unusual for thesis students to begin by only spending 5 to 10 hours a week on their thesis at the start of what they plan to be their last semester. To think that this is reasonable is to live in a dream-world.

A master's thesis is the equivalent of two to three full subjects. This implies that a thesis is equivalent to 2 to almost 2 ½ months of work at 40 hours/week, that is anywhere from 350 to 450 hours of effort (or 1 ½ to 2 months of 60 hours/week of work.

The simple calculation of the effort required to do a thesis implies that students should start working on their thesis much earlier than commonly believed. This is especially true since the deadlines for these are normally some time before the end of the term. In particular, for a usual Spring deadline in early May, the students should on average be working very intensely on their thesis in February.

Cannot Accelerate Easily

A thesis requires more than just hours of effort; it also requires time for ideas to develop and mature. It's a mistake to think you can do a master's thesis just by putting in a lot of effort during a short period, such as a summer.

A thesis consists of roughly two phases. The first is one of formulation, in which you try out various ideas, meet with potential advisors, investigate sources of data and methods of analysis, etc. This process cannot be compressed easily. Typically, the formulation phase takes about 2 to 3 months of about 5 to 10 hours a week.

The second phase is that of execution of the work. This phase takes 2 to 3 months, but demands at least 25-30 hours a week, if not more.

Schematically, a balanced effort might look something like Exhibit 3.1a. What actually tends to happen to the student who does not look ahead is more like Exhibit 3.1b.

Exhibit 3.1a: **A Balanced Allocation of Effort to a Thesis**

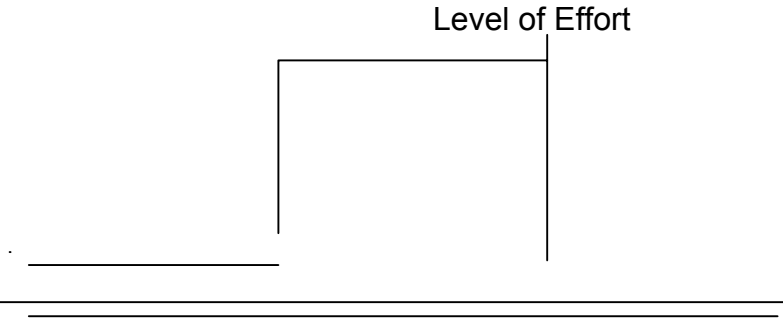
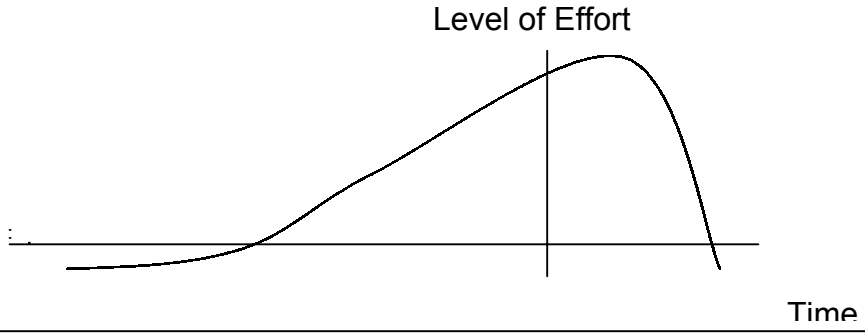


Exhibit 3.1b: **A late and bad Allocation of Effort to a Thesis**



There are External Delays

Another major error most thesis students commit is to forget that the completion of their thesis depends on the cooperation of many other persons and services. These are never available exactly when desired, and least accessible when most needed, towards the deadline. Just when you need computers for those final runs, and photocopying services for the final drafts, so will everyone else. Your advisor, moreover, cannot be expected to be waiting around with nothing to do, available to read drafts whenever you get these ready. Advisors too will be most busy and least accessible at the end of the academic year, just before graduation. It may easily take your advisor a week to read and comment on any extended draft. Turnaround time from you to advisor and back may easily become a real problem.

To counteract these inherent delays you must plan to have your thesis ready, and thus start working on it in earnest, much earlier than you might imagine. Consider Exhibit 3.2 below, which projects the time required to finalize the thesis, and then estimates the latest date at which these tasks should be accomplished. In short, to hand in a thesis on time, the bulk of the research must be completed about 1 ½ months before the deadline!

Naturally, you must also consider that important delays may occur in the research itself: you may have to wait for data to arrive, have difficulty in arranging field visits or appointments, etc.

Exhibit 3.2: **Typical Working Deadlines needed to meet formal deadline for thesis**

Activity	Time Required (weeks)	Deadline			
Thesis Hand in		T-0	May 10	Aug 20	Jan 20
Final Word Process, Copying	2	T-2	Apr 2	Aug 6	Jan 6
Final Advisor Review	1 to 2	T-3 ½	Apr 15	July 25	Dec 20*
Writing of Final Draft	2 to 4	T-6 ½	Mar 30	June 30*	Nov 30*

*Holidays, when the advisor is not available, means that you need more lead time.

Research is Also Iterative

Readers must also bear in mind that research is not a linear process. Because it is a venture into some unknown, because we do not know quite where we are going or how we are going to get there, we cannot expect to get there in a straight shot. Research definitely does not consist of stepping through a series of steps directly from formulation to conclusion.

Research is typically iterative. Experienced investigators quite usually start off with a trial solution, use exploratory data and analyses to see how things work out and then – having learned what seems to work and what does not – proceed to repeat their analyses in detail. It is quite normal to test out a method of investigation, execute a study, and then to replicate it somehow by way of verification.

You will find that something similar is appropriate for your thesis – or will be imposed on you by your advisors. It is entirely possible, if not most likely, that your first drafts will require substantial revision. Experienced professionals writing for journals routinely are required to carry out at least one set of revisions, as can be verified by reading the fine print at the bottom of the first page of most journal articles. You may expect the same.

You will be severely mistaken if you assume that you can write a chapter definitively early on in the process of doing the thesis. The fact is that the content of any chapter should reflect both the results you have achieved and the logic of the argument you will use to make your point. As these elements only become clear towards the end of the research, only then can you correctly finalize each of the chapters. For example, although you may have a reasonably good idea of the literature for the introduction, your advisor is likely to insist that you expand it or alter its focus as you near completion. In short, allow time and plan for revisions as you proceed.

You can make your time and efforts be much more productive it you recognize the iterative nature of research. You can do this by structuring your work to take advantage of the phenomenon. Thus if you plan to do three case studies, for example, you might consider doing them one after another rather than simultaneously. By doing them in series you can profit from lessons learned earlier, whereas by doing them in parallel you may be repeating the same mistakes unnecessarily.

The net result of these observations is that you should allow plenty of time for iterations on your drafts of the thesis. Do not presume that your polished draft will be reviewed for detail only and can quickly be revised. It may come back

with suggestions that imply major rewrites if not rethinking. Allow time for this to occur.

The point of this chapter is that you owe it to yourself to plan your time carefully, and to start early.

Methods for Planning Your Time

The section presents three standard approaches for helping you plan and schedule your time. These are: scheduler, bar graphs of the level of effort over time, and the Critical Path Method (CPM). These methods can be executed on a variety of programs available for personal computers.

Scheduler: A scheduler program (such as Outlook ®) allows you to schedule tasks to specific times, and to display them in many ways.

A Time Chart is a useful supplement to a scheduler. It focuses your attention on the schedule, on when various activities should start and finish. It is also sometimes referred to as a Gantt Chart.
A Time chart is simply a table, with activities listed vertically and time (typically in months) horizontally. For each activity there is a horizontal bar underneath the months during which you will do the activity.

Bar Chart of Level of Effort: This device illustrates the level of effort required for the project at any time. It is simply a histogram showing effort vertically, by week or month horizontally. It is constructed by associating the level of effort (in hours/week, say) for each activity in the time chart. When this has been done for all activities, you can sum vertically to see how well the effort implied by your plan corresponds to the time you actually can devote to your project considering your other obligations and needs (to sleep from time to time, etc.). The bar chart focuses attention on the practical implication of a schedule (if it says you should be working 80 hours/week at some time, watch out! Reschedule!).

A bar chart of level of effort can be easily constructed from a standard spreadsheet program. By arranging the tasks in rows and months in columns, and entering the anticipated effort for any task in any period in the corresponding cell, you can simply sum up the projected level of effort for each period. These results can be graphed or displayed as a bar chart.

Critical Path Method: (CPM) helps you identify crucial elements that could, if delayed, interfere with the target date of completion (and thus with your plans for graduation).

The object of CPM is to determine the sequence of activities which requires the longest time from start to finish, the “Critical Path”. Knowing the critical path for

your effort, you can then determine first whether the project is feasible as defined in the time allotted. If this work is not feasible, the critical path indicates which activities have to be redefined or hurried up so as to shorten the path. The critical path also indicates when each activity in the path must be completed, so that the subsequent activities can be completed in the time remaining. This information helps you adjust your effort if you start falling behind.

The procedure is basically simple. You first have to determine the organization of the overall effort, specifically how it is composed of individual activities. This involves essentially three steps. You must, as illustrated in Exhibit 3.3:

1. Identify the principal activities that must be done to complete the total job. For a thesis, these would be: "identify topic," "get approval of advisor," "obtain data," "analyze data," etc. These constitute the "activity list.
2. "Estimate the time required to complete each activity.
3. Determine which activities must precede which others (for example, "obtain data" must come before "analyze data," etc.). This information is the "predecessor list."
4. The computer organizes the activities into their logical sequence on a diagram, drawing arrows between activities which must precede each other.
5. Calculates the time along the several paths formed by these arrows. The longest is the critical path.

If the time implied by the critical path is excessive, you will have to change your schedule if you wish to complete in time. You can do this by reducing the scope of some activities (if not eliminating them completely) so that they will take less time.

A major usefulness of CPM lies in its ability to show a person which activities require most attention, and thus to understand where to put priorities to complete a job (the thesis) on time

Exhibit 3.3: **Kind of Data Required for a Critical Path Analysis**

ACTIVITIES	TIME IN WEEKS	PREDECESSOR TASKS
1 - Organization	7	-
2 - Contact data sources	7	1
3 - Review literature	7	1
4 - Define methodology	1	1
5 - Write the introduction	2	3,4
6 - Do and write technical analysis	4	3
7 - Do and write the economic analysis	2	3,4
8 - Do and write the functional analysis	2	7
9 - Write conclusion and recommendations	2	5,6,8
10 - Type draft	2	9
11 - Advisor Review	2	10
12 - Type and proof final copy	2	11

4. LITERATURE SEARCH AND BIBLIOGRAPHY

Objectives

A good literature search is basic to effective research. This must be emphasized: A number of students treat the effort rather lightly, thinking that bibliographic work is little more than scholastic pedantry and that, if they must do one, they can adequately create it at the last minute, somewhat after they have written the conclusions. In these ideas they are grossly mistaken.

First of all, you need to do a careful literature search because you need to understand the facts of your topic. You can hardly be effective if you do not have a firm grasp on its reality and context, if you do not appreciate the basic forces at work and see how they have played out in other circumstances. More often than I care to remember, I have seen much hard work trivialized by the fact that the person was working on something that had already been demonstrated to be wrong, and they had not bothered to verify.

You neither want to repeat what others have done, nor ignore the contributions and data they provide. You should appreciate that many people probably have -- somehow and somewhere – been concerned with the same kind of issues as yourself. You need to find out exactly what they have done. It is wasteful to repeat their work instead of moving further on.

Other studies are frequently a source of valuable data for your own analysis, either directly or through some from of reinterpretation. Since the collection of data is typically one of the most time consuming and expensive portions of any research (see chapter 5), it is really desirable to spend time seeing to what extent data can be found ready-made.

Secondly, you need to understand the theories relevant to your issue. Understanding your field means that you should be familiar with the different ways people view the problem, with the opposing schools of thought. In most areas of research, certainly for all policy issues, there exist different if not contradictory theories. For example, physicists debate various theories to explain the relationship between electromagnetism and gravity, automotive engineers argue about the best fuels and power plants, and economists never all agree on how to manage the economy. The existence of opposing points of view on a topics is almost a necessary complement to a research question. A question implies uncertainty, differences in ideas about the result. To be most effective, you should carefully understand what the alternative views are on your subject.

There are also various schools of thought concerning methodology. Each discipline and profession is likely to look at the same situation quite differently, emphasizing different aspects of a problem and different methodologies of research. For example, in research on how people choose between products or designs:

- Economists might emphasize price and be inclined to use econometric analysis;
- Psychologists might give priority to cognitive perception and prefer laboratory experiments with human subjects; and
- Engineers might place more importance on performance and be inclined to test the materials.

As a researcher you ought to be familiar with the most significant possible frames of reference that concern your issue, and with the consequent methods to attack it. At the start of your work you in effect choose between the alternate pathways. At the end you will have to deal with the criticisms and arguments that other approaches imply.

To make the point you want to make in your research, to make it well so that it can be appreciated widely, you should be able to explain why your approach is superior to alternative explanations. If you cannot do that, you really have not proven anything.

The short of all this is that a careful literature search is one of the most cost-effective investments you can make of your limited resources.

Finding Material

A good literature search combines two complementary elements: use of collegial advice and systematic searches. Unfortunately, most students do not know how to use either effectively, and tend to get involved in a fairly short-sighted ineffective plodding from reference to reference.

Quality versus quantity is the essential problem in a literature search. Quality is of course what we want. We should be doing the literature search because it helps us, and we want to uncover those elements that are truly helpful. The other material, the references that do not help us, can be discarded.

Beginners often mistake quantity for quality. Perhaps it is associated with the idea that a bibliography is some kind of gloss that makes a report look good. Perhaps it is because it is easier to collect references indiscriminately than to think hard about them. An anecdote illustrates the situation. I remember a doctoral candidate whom I met on a visit. He pointed proudly to three file drawers full of references and told me that he was almost finished with his thesis

because he “had all the data”. In fact, he never finished, he apparently did not know how to organize the material, how to make sense of it.

To obtain a first-rate bibliography you need to identify the key references, both in your own line of work, and in the different approaches to the problem. You need to determine:

- What are best references in the field?
- What are the opposing ideas in the field, and which references explain them best?

Networking is an effective way to find the best references. Consult knowledgeable colleagues or advisors. They have typically been in the area many years and can recall a lot of the important references. A trick here is to consult them not just once but several times. It often takes people a little while to see where you really want to go and to recall the important ideas. To minimize possible aggravation, you should consult their articles to see whom they refer to, and should look at their reading lists for courses if they teach.

Once you get into the library, you should systematically examine a number of key bibliographic references which will point you rapidly to all kinds of material which you might otherwise ignore. First of all there are *Abstra*cts. These volumes, typically issued annually in various fields, try to reference every article on a subject, as defined by keywords. In addition to looking at the special technical abstracts, such as the *Engineering Index* or *Chemical Abstracts*, also consult the *Economic Abstracts*. (Economists tend to get into everything, especially as regards policy.)

Students will also find it useful to consult the Dissertation Abstracts that have been prepared by UMI. According to them, this database and previous paper publications cover "dissertations accepted at accredited U.S. Institutions since 1861. Selectively covers masters’ theses, Canadian dissertations, and British and other European dissertations.” MIT students can consult it online through the MIT Library system: http://libraries.mit.edu/lists/db.web.html

Next, look at the NTIS (National Technical information Service) reports. Issued annually, they are supposed to refer to every research report prepared for and accepted by the US government. These reports can also be ordered cheaply, if unavailable in the library. They often provide good data.

For policy issues you may find it helpful to refer to the *Congressional Index* of the U.S. Congress, which cites legislative hearings held by specialized committees of the Senate and House of Representatives. These typically involve testimony by prominent experts and are a good means to understand different aspects of a policy issue.

A most important remark for anyone doing a literature search: write down the full reference (including page numbers and other details) of any work you think you might eventually cite. You may think this is unnecessary because you will remember how to find it, but two months later many people find that they have lost track of references. It is aggravating to have to look for everything all over again, especially when you are preparing the final draft of the bibliography and your graduation deadlines is only a week away.

Computer Searches

It is much easier to use a computer to search for a reference than to use the traditional index cards. They are particularly convenient when you can use them remotely, from your office or home.

But beware: Computer searches can generate a lot of useless material. They emphasize quantity rather indiscriminately. You need to complement computer searches with some ideas – usefully obtained from experienced colleagues – about which authors or research groups have done the best work, and which journals are likely to have the most relevant and most reputable work.

Beware especially of the web! It is seductively attractive – and frequently untrustworthy. It is attractive because it offers quick, 24-hour, convenient access to pages with statements about every conceivable topic.

The web is untrustworthy because there is no – repeat no – quality control. Practically anybody can post whatever they want. There is no objective review of anything that appears.

In looking at the web, you are looking at press releases. The people posting material on the web want to make themselves or their ideas look good. They can present whatever “facts” they want, can give you only the good news, and have little reason to present opposing ideas fairly if at all.

The material on the web cannot be double-checked. It is here today and may be gone tomorrow. Its sources can vanish without trace. Newspapers at least are archived and many can be viewed on microfilm. The web, however, is a transient source of suggestions, some excellent, others most dubious.

Bibliographic Systems to be Avoided

Many systems of preparing references and bibliographies exist and are “correct” in the sense that they meet acceptable norms of scholarship and are used by journals. But some of these systems turn out to be exasperatingly difficult to prepare in practice. So be careful about your selection.

The reference system should be easy to use, both for the writer, and the reader. Using this simple criterion you should reject several broad categories of reference systems right away, unless they are imposed by the traditional requirements of some journal. You should avoid systems with:

- Footnotes at the bottom of a page. For many people footnotes on the same page are a distraction and break the flow of the main argument. (Personally, I hate them!) Others like them, however.
- References by number in the text: Since these numbers do not convey any substantive significance, it is difficult for the author to check in the text if the right reference is cited (What if the author makes an error?). Similarly, the reader cannot easily grasp who is being referred to, but is forced to flip to the back to find the reference.
- References by number in the bibliography: Same remarks as above, plus the fact that any arbitrary numerical organization makes it difficult to find the work of any particular author. Alphabetical orderings are preferable.
- Superscripts: This just makes reading and printing more difficult. The alternative is to give the references in parentheses straight in the text.

Recommended Bibliographic Systems

The system that seems to provide the most useful balance between simplicity, intelligibility and reliability is the 'Harvard' method that gives the authors names in the text. It has several advantages:

- Because it uses names rather than numbers, both the author and the reader can have a direct idea of who is being cited, and if this reference is appropriate.
- The reader will also be able to find references easily in the bibliography.
- References correct for any citation are still correct even if the text is radically rearranged.

In the text, the recommended method gives all references parenthetically, to author and year. Unless confusion would result, the citations should come at the end of a sentence; otherwise, they should be at least at the end of a clause. Thus: "To expedite their progress, thesis students should pay careful attention to the guidelines for thesis definition and preparation (de Neufville, 1998)." The parenthetical material giving the reference in the text has specific forms for special conditions. See Exhibit 4.1.

Exhibit 4.1: **Ways to Refer to Material**

If you refer to	Form to Use	Example
Several articles by same author in same year	Alphabetical tag on year	(Clark, 1998a) (Clark, 1998b)
Two authors	Both names	(McCord and de Neufville, 1985)
Many authors	Lead author et al	(Schweppe et al, 1985)
Page numbers for a quote	Page references after year	(Tabors, 1992, pp. 18--20)

In the bibliography, you should list references alphabetically by first author, exactly as cited in the text. For any particular set of authors the references are chronological, with the more recent references first. Thus:

Marks, D. H. (1990a)...
Marks, D. H. (1990b)...
Marks, D. H. (1989)...

The format for the references in the bibliography starts off with the authors by last name, and then initials followed by the data. Thus:

de Neufville, R., Chin, F., and Rebelo, J. (1973)...

For a journal article, the string continues with the article's title (in quotes), the journal's name in italics, the volume number, the issue number, and the pages in the journal. For example:

de Neufville, R., and Grillot, M. (1982), "Design of Pedestrian Space in Airport Terminals," *Transportation Engineering Journal*, American Society of Civil Engineers, 108, TE1, pp. 87-102.

For a book, the string proceeds with the title in italics, the publisher, and publisher's location. Thus:

de Neufville, R. (1991), *Applied Systems Analysis -- Engineering Planning and Technology Management*, McGraw-Hill, New York, NY.

Note that for the United States you should refer to any state by its standard two letter postal abbreviation, in this case NY for New York. If there is a possibility of ambiguity, refer also to country: Birmingham, England or Birmingham, AL (USA).

Government documents require special attention. The overall format should be the same as for other entries, but some particular points should be observed:

- Each official document that is not the responsibility of individuals, should be referred to under the name of the highest authority over the issuing agency. Thus you should cite:
  "United States, Department of Transportation..."
  rather than
  "Department of Transportation..."

  The purpose of this is to avoid confusion when different governments or portions of government each have agencies with identical names. For example, both the United States and several individual states have "Departments of Transportation".

- Many independent authorities may exist within a nation, for example state governments or independent boards. For instance, you would cite:
  Massachusetts, Department of Transportation..."
  or also
  "Port Authority of New York and New Jersey...

  The latter is not, strictly speaking, part of either the US Federal government or the state governments.

- Differences should be made between independent branches of the government, specifically between the Congress and the Executive. Thus:
  "United States Congress, House of Representatives..."

- When some minor part of the government issued the report, its superior agencies should be listed hierarchically starting with the highest. For example:
  "United States, Federal Aviation Administration, Bureau of National Capital Airports..."

References to theses should cite which department or program the work was done for. This is because librarians often file these this way, and thus need the information to retrieve the reference. Thus:

> Estrin, D. (1983), "Data Communications via Cable television Networks: Technical and Policy Considerations," S. M. Thesis, Technology and Policy Program, Massachusetts Institute of Technology, Cambridge, MA.

If the citation has not been published, then sufficient information ought to be given so a reader can hope to track down the report. For example:

- Electric Power Research Institute (1979), The Market Potential for Electrolytic Hydrogen, EPRI Report EM-1154, Los Altos, CA.
- de Neufville, R., Thesis Definition and Preparation – some General Guidelines, MIT Technology and Policy Program, Cambridge, MA (USA), http://command.mit.edu/

You will also encounter special situations. These can be handled in a number of ways. Stick with the general principles outlined above, and you will be OK.

5. DATA COLLECTION

Purpose

The gathering of evidence is an essential part of research. Evidence constitutes the link between theory and reality. It forces you to translate abstract notions into practical terms and thereby make them useful. Conversely, the confrontation of facts or specific counterexamples with theory enables you to distinguish between correct and incorrect models.

Creative speculation is often crucial to significant advances. For many, it has great appeal as it seems bolder, deeper and more imaginative than detailed, empirical work. Speculation can also be pure fantasy, pointless wanderings from inappropriate premises. Evidence provides the discipline that enables you to distinguish productive and unproductive speculation.

The reason to collect data is thus to determine what is, so that we can match this reality with our models. It is therefore crucial to be careful about our concept of reality: what is a fact? What reality are we trying to define?

Data collection also can be expensive in terms of money, time and effort. Since you inevitably have limited resources, it is therefore important for you to gather valid data efficiently. This task is often far from simple.

Concept of Reality

Facts do not emerge of themselves in any absolute sense. You perceive them through some means of observation: your senses, some mechanical device, or some form of questionnaire. None of these instruments are always perfect. Even when they themselves are flawless, they may be misapplied. Your perception of reality is thus affected by the quality of the instrumentation.

Difficulties with instrumentation and measurement generally can lead to a variety of distinct problems. The following discussion focuses on four major issues: Reliability, validity, representativeness and significance.

Reliability: Reliability, when associated with measurement, refers to the ability to replicate an observation of a stable phenomenon. Do we get the same answer if we measure something repeatedly? If yes – within tolerable limits – then the measurement is reliable.

Reliability is evidently a most important characteristic of instrumentation. If readings differ significantly each time we use an instrument, or between

instruments, or between observers, it is inappropriate to have faith in the results. An essential part of the development of instrumentation is the determination of the conditions that lead to reliable results. Whether we are observing temperature or unemployment rates, we require means of observation, that is instruments, which are reliable. (Note that the word instrument denotes not only devices for measuring physical phenomena, such as a spectrometer, but also devices for measuring social phenomena, such as questionnaires.) Reliability is the factor that enables us to perceive real changes in the phenomenon observed.

As emphasized in basic physical laboratories, standard conditions (as for temperature and pressure) are required to achieve reliable measurements. The standard conditions must of course be relevant to the nature of the phenomenon.

Questionnaires or interviews are notoriously unreliable unless controls are applied rigorously. The personal relationship between the persons involved may easily distort the responses and lead to quite unreliable results. Different observers, or the same observer in different situations, may phrase the questions differently or with a different nuance. The respondent may sense the question differently or may take it more or less seriously.

People who collect data by interview must therefore pay particular attention to standardizing their questions. A good way to do this is by using computer generated or written questionnaires so that the same questions are asked, in the same way and the same sequence, each time. Even if the questioner cannot get the respondent to sit at a keyboard or provide written answers, it is useful to use a predefined questionnaire as the basis for the oral questions.

Validity: Reliability does not guarantee that observations are correct. It is entirely possible to replicate erroneous readings consistently. Instruments are often biased. A scale, for example, may easily be loaded to give inflated readings; a person may be color-blind and systematically fail to observe some colors.

Validity refers to the degree to which a measurement provides a correct measure of a phenomenon. It is a concept quite different from reliability. Just as one measurement may be reliable yet not valid, another may be valid but unreliable.

The question of validity is especially problematic for measurements done concerning individuals. People have all kinds of respectable reasons for not revealing or for distorting their feelings. They may begin by thinking that the questions are an invasion of privacy. They may not trust the interviewer not to use the information against them. They may feel embarrassed by their answers (will people think my income too low?). They may not wish to contradict some official position expressed by their superior, or to express some idea that might seem disloyal (can one normally expects many employees to speak ill of a major new product just introduced by a company?) Finally, it is presumptuous to

presume that people have thought about the issues that concern the interviewer or know their feelings on a subject.

Validity is difficult to determine. How can you know that you are getting the "truth" when all you can observe is some surface feature? How do you know, for example, that a person's response reflects their true feelings? In this validity is quite different from reliability, which can be judged by replication. To increase the probability of obtaining valid measurements interviewers should, at a minimum, use a spectrum of tactics:

- Trial questionnaires used with trusting collaborators with whom the interviewer can discuss the results (see further discussion in section on sampling in this chapter);
- Questions that refer to actions a person can imagine taking (e.g.: "If the election were held today who would you vote for?" as opposed to "How do you feel about the candidates?");
- A variety of questions that probe a person's feelings on a topic in different ways to check for consistency (e.g.: "Do you agree with the Pope's position on abortion?" and "Are you a member of Planned Parenthood?").

Representativeness: As a general rule we are interested in the behavior of a large class of items, for example: the behavior of steel beams, the evolution of stars, the customers' demand for products. Our limited resources only allow us, however, to measure a portion of any large set. The issue is: how do you make sure your limited observations represent the whole?

If your set of observations somehow omits elements of the class with special features, you may get a biased reading on the behavior of the class. For example, if you wanted to know how people liked a new product, you should not only ask people who bought the product -- if you did so you would omit the people who disliked it or couldn't afford it, and would miss their reactions. You must therefore be concerned with whether the items you observe are a reasonable cross-section of the class as a whole, with whether they are representative.

The issue particularly arises when you do not know the composition of the class of items in advance, or do not know it in relevant terms. You might then in ignorance omit some elements and obtain biased date. However, if you do indeed know what the different significant components are, you can sample the population efficiently by a variety of means (see discussion of sampling further on in this chapter).

Unrepresentative measurements frequently occur because the plan of the observations, typically designed for convenience, systematically omits aspects of the problem that turn out to have been important. For example, it might seem both reasonable and convenient for the questioner and the respondent to survey airline passengers by a 'random' sample of people waiting in any airport

departure lounge. Such a sample would, however, be systematically biased against experienced travelers that tend to arrive at the last minute, and who might reasonably have quite different views on air travel.

To guard against obtaining unrepresentative observations, the designer of the data collection effort should carefully consider:

- Which elements of the population will be systematically omitted from the survey; and
- Whether there are logical or behavioral reasons to believe that these elements are significantly different from those that are sampled.

In any event, the observer should avoid collection strategies based primarily on simplicity and ease of effort. These characteristics themselves may be the source of bias: volunteers for a survey may be extroverts, for example, and thus quite different than the population as a whole.

Significance: Finally, we must be concerned with whether we are asking the right questions. Are we really observing the features of a system that will explain its behavior? The answer here is only obvious if one has a specific model to test.

It is not at all evident that you know what the right questions are when you are in the process of trying to develop a model or theory. As it often occurs that researchers try to develop theory and evidence simultaneously, you may be at somewhat of a loss to know what to do at first. The answer is neither. Research is iterative. You need to formulate, and reformulate, your research question so that you can be sure you are asking the right questions before you engage in an expensive data collection effort.

Efficiency in Data Collection

You will want to maximize the amount of useful information for your efforts. Conversely, you will want to collect the necessary data as inexpensively as possible. The issue is vital because the time and effort spent to gather data could be very great indeed.

The focus must be on information rather than data itself. Data and information are definitely not the same. The sheer quantity of observations, however reliable, valid, and significant, does not represent the amount of information. The data may be redundant. If five different editions of the daily paper report who won the election yesterday, for example, we have five observations (the editions) but only one piece of information (the result).

Redundancy of observation is useful when the measurements are perceptibly unreliable or when the population being sampled is not homogeneous. The redundancy then defines the distribution of the information.

As a practical matter, the plan for the efficient collection of data include two elements:

- Some arrangement for trial observations of pretests; and
- A sampling strategy.

Pretests: A pretest is simply a small scale trial effort at collecting data. To the extent possible it is in all respects like the full effort being contemplated except that it involves only a small fraction of the effort. It should be part of any serious data collection efforts.

The object of the pretest is to verify that the larger scheme is both practical and useful. Researchers routinely find that their original plan for gathering evidence is unsatisfactory. Many things can go wrong with their original ideas and some almost certainly do. The role of the pretest is to anticipate most of these difficulties so that the researcher can redesign the original plan to avoid initial mistakes, and thus insure that the data collection is most productive.

A successful pretest requires careful thought. For the reasons described previously, it is not sufficient merely to see if the data collection is feasible or replicable. We must be concerned with validity, representatives and significance.

Two elements improve the likelihood that the pretest will lead to useful redesigns of the data collection effort. One is to have a preliminary theory or model in mind that one is planning to test with the data. Such a model implies some particular responses and results, and data may then be gathered on those. The data collection effort is then certain to be useful, at least to confirm or rebut something specific. If one collects data without a model in mind, one runs the risk of being left with useless, irrelevant statistics.

Secondly, it is helpful to apply the pretest in circumstances that allow you to discuss the results with knowledgeable people. They can help you determine why various things went wrong and how you might correct them. If you use personal interviews, it is important to try to obtain the cooperation of the subjects of the original pretest, so that they themselves can help you redefine the measuring instrument.

Sampling strategy: Sampling strategy consists of devising a plan of observations that maximizes the amount of information for a given number of observations. The efficiency of a sampling strategy is usually defined statistically either by the narrowness of the confidence limits that can be obtained with a given number of observation or, conversely, by the minimum number required to establish prescribed confidence limits.

The most efficient sampling strategies are 'stratified'. These derive from the following facts:

- A heterogeneous population (almost always) consists of different subgroups with various degrees of variance;
- The variance of the entire population is the sum of the variance of each subgroup plus the variance between the subgroups themselves;
- The parameters of the entire population are obtained more efficiently by sampling the subgroups, thereby by-passing the variation between subgroups; and
- The scheme is most efficient if the observations are assigned to each subgroup in accordance to their size and variance.

Many sampling schemes exist. They are tailored according to the types of distributions and the degree of prior knowledge one may have about the population.

As a rule, the more you know about the population in advance, the more efficiently you can design the data collection. This is another reason to use pretests - if you can thereby estimate the distribution of variance of responses in any subgroup, you can increase the efficiency of your information gathering.

There are two main types of stratified sampling schemes: proportional and disproportional. The former simply allocates resources in direct proportion to the size of each subgroup. It is easy and only requires reasonable estimates of the relative size of each subgroup. Disproportional sampling as a rule varies the number of observations in direct proportion to the standard deviation of each subgroup and inverse proportion to the square root of the cost of each observation in that subgroup. This may require quite precise prior knowledge of the situation and is certainly also difficult to apply if you are concerned with many parameters.

You may find these references useful:

- Campbell, D.T. and Stanley, J.C. (1966) *Experimental and Quasi-Experimental Designs for Research*, R. McNally, Chicago.
- Frigon, N. L. (1997) *Practical Guide to Experimental Design*, Wiley and Sons, New York, NY.
- Mason, R. L. (1989) *Statistical Designs and Analysis of Experiments with Applications Engineering and Science*, Wiley and Sons, New York, NY.
- Montgomery, D. C. (1997) *Design and Analysis of Experiments*, 4th ed., Wiley and Sons, New York, NY.
- Rasch, D. (1989) *Experimental Design: Sample Size Distribution and Block Design*, D. Reidel, Dordrecht (Netherlands) and Boston, MA.

6. USE OF CASE MATERIAL

One or more case studies may constitute the evidence you will use in your thesis. A case study focuses on a particular example of what could be a much larger collection of similar cases. This detailed examination of a particular situation can take on many forms, such as the:

- Operation of a prototype plant;
- Analysis of data from a particular city, region or country;
- Application of a particular method, etc.

Case studies often prove to be confusing. It is difficult to know what information to collect. Researchers, knowing that a case study by definition requires a detailed understanding of a situation, often get lost in this detail. They may have great difficulty in relating the details to their thesis. Some eventually focus on the detail itself, acting as if that by itself would demonstrate their hypothesis. Others get frustrated by the detail and simply stop collecting it. This issue invariably seems to be: what and how much detail should be included in the case study?

Doing a case study well requires you to be clear about the role of this evidence in your thesis. You must know how the information you are assembling will help you maintain your argument. This knowledge defines both the kind and quantity of detail required in the study.

This case study can fulfill many different roles in the logic of your thesis. Each of these has quite different implications for the conduct and nature of the case study. The object of this chapter is to identify the major roles a case study can have, and to indicate how these should shape the study.

In general terms, case studies can either represent applications of existing theory or methods, or be part of the development of such theories. Within each of these two categories there are further possibilities. As these two major alternatives have distinct requirements for the case study, the discussion centers around them.

Application of Theory

Case studies are often applications of a theory or method. They can perform several functions in this way: they may demonstrate a theory, illustrate its use, or simply apply it for some specific purpose.

Demonstration: Case studies often serve to show that a method actually works as intended. This kind of "proof by demonstration" is common in a number of specific fields. In computer science, for example, it is usual to demonstrate a

new algorithm or procedure by constructing a program that executes this method. Similarly, James Neely demonstrated his method for evaluation research projects by showing that it performed easily and to the satisfaction of the users in a specific application in the automobile industry. (Neely, J. (1998) "Improving the Valuation of Research and Development: A Composite of Research Options, Decision Analysis and Benefit Valuation Frameworks," Ph.D. dissertation, Technology, Management and Policy Programs, Massachusetts Institute of Technology, Cambridge, MA).

Illustration: A case study can also illustrate a method, process or problem. This kind of application provides the researcher with the opportunity to discuss the strengths and weaknesses of a method, and to indicate the kinds of changes that might be desirable. This is what Luis Paz-Galindo did (Paz-Galindo, L. (1997) "Strategies for electricity Supply in the Province of Mendoza: A Multi-Attribute Trade-Off Analysis Application," S.M. Thesis, Technology and Policy Program, Massachusetts Institute of Technology, Cambridge, MA).

Application: The case study may also be a straight application of an approach, done for the results that can be obtained. For example, Magali Smets applied Dynamic Strategic Planning to the development of the Hibernia Oil Field in the North Atlantic (Smets, M. (1999) "Dynamic Strategic Planning for System Design: An application to Oil Field Development", S.M. Thesis, Technology and Policy Program, Massachusetts Institute of Technology, Cambridge, MA).

Implications for Case Studies: The nature of a case study, when it is part of an application of theory, is defined by the requirements of the theory. For a cost-benefit study, for example, one requires data on quantities of effects and on their prices.

In carrying out a case study for application one can thus focus on two simple steps:

- Identification of the kinds of information required by the method; and
- Collection of the data required, disregarding other details.

In this kind of situation there should be relatively little question of what kind and how much detail should be assembled.

An interesting aspect of these kinds of case studies is that the data can often be invented by the researcher. For many applications one does not need to know the real situation. For example, if one wants a proof by demonstration, all one requires is a set of data that have the same kind of structure, of complexity as real problems; one does not need to mimic a particular problem. Likewise, in the use of a method one can input a range of data for any particular parameter and carry out a sensitivity analysis to show what kinds of results would result from different assumptions.

Development of Theory

The preparation of a case study that is intended to help develop and validate a new theory is much more difficult. The nature of case studies that are applications of theory are shaped by that theory. What is to determine, what is required for a case study when that theory is either vague or non-existent?

The proper approach to the case study depends on the research method used: deductive or inductive. The principles behind each are quite different, and thus have different implications for the case study.

Deductive Approach: The deductive approach starts from some assumptions or known facts and proceeds, by logical deduction, to derive subsequent theories and their implications. It proceeds from the general concept to the particular observations. This approach is also referred to as the Cartesian method, after Rene Descartes, a seventeenth century French mathematician.

Doing a case study is easier under the deductive than the inductive approach. This is because the deductive approach does start with some sort of theory. This provides specific guidance as to the nature of data that needs to be included in the study.

In this respect the procedure is similar to that for case studies done as applications:

- Define the theory;
- Identify the specific data relevant to its proof; and
- Collect this information.

Inductive Approach: The inductive approach is the opposite of the deductive. It proceeds from the detail to general concepts. The practice here is to collect many different observations, to look for common patterns and thus to enounce general theories. It was the path taken in the main by Darwin in developing his general theory of evolution, for example. This approach is also referred to as Baconian, after Francis Bacon, a seventeenth century Englishman and one of the first "modern" scientists.

As case study that purports to examine a situation and to find out what happened is most difficult to carry out successfully. With little or no theory to guide one's efforts to collect data, one is pretty much left to do so indiscriminately. This process is inherently cost-ineffective: much of the material gathered will inevitably turn out to be irrelevant or tangential, so that the effort necessary to gather what one eventually wants is much greater than it would have been if one had started out with a good idea of what one wanted.

Use of a case study as part of an inductive effort is also, to a great extent, a contradiction in terms. The essence of the inductive approach is to draw general conclusions from many particular examples; the essence of a case study is to be unique. Evidently, I do not recommend inductive case studies!

Limits on Usefulness: The use of a case study as part of an argument to develop or validate a theory suffers from limitations inherent in the unique nature of any case study, and thus unavoidable. These are that:

- A single case study cannot prove a general theory, and it is really a single anecdote; and
- It is always questionable whether the single case study is representative of more general situations.

A single case study cannot prove a general theory, since it cannot demonstrate that there are no counter-examples. The case study can at best corroborate a general theory, show that it is plausible. This is what Renata Pomponi did in her studies of product design in the aerospace industry (Pomponi, R. (1998) "Organizational Structures for Technology Transition: Rethinking Information Flow in the Integrated Product Team," Ph.D. Dissertation Technology, Management and P9olicy Program, Massachusetts Institute of Technology, Cambridge, MA).

The fact that it is extremely difficult to demonstrate that a particular case is representative of a general situation places definite limits on the kinds of conclusions one can draw. Simply put, you cannot expect to go from a single case to a general theory. For example, it is inappropriate to use a single case study of a design process of refineries in Indonesia in the 1990's, to argue a theory about the design problems for all kinds of projects at any period, for all of Indonesia, let alone for all developing countries. Recognize at the start that a single case study can only indicate a possibility.

A single case study can, however, disprove a general theory. It can be a counter-example, a demonstration that the general theory does not work.

Advantage of Several Cases

It should be obvious that using more than one case as evidence to support a thesis can strengthen the argument. The logic seems compelling: more information means a better understanding. The use of several cases can thus be a critical element of a successful thesis.

Dealing successfully with several cases requires careful thought. The differences between the cases may lead to confusion. This is because the results of each case will inevitably not be identical. For example, the

effectiveness of a design process in two companies will be different. In one it might be a success, in the other not. Such a contradiction poses a problem.

If you had only one case, you might have thought - erroneously - that the design process was clearly either successful or not. With two (or more) cases; you cannot tell. To what factor can you ascribe the differences between the results? To differences in the size of the companies? In their location? Mix of products? Management? You need to consider these inevitable questions before you begin your case studies.

When you plan to do several case studies you need to identify the factors that are most interesting or important. In thinking about a case study of a refinery in Indonesia for example, you would need to decide whether it is most interesting to focus on refineries, on cultural differences, on the effect of size, etc. This choice determines the kind of additional cases you should select.

You should choose complementary cases to span the dimension that is important to you. Thus if you are interested in the effect of size of a company, your cases should cover the possible range of that factor, from a small company to a large one.

The complementary cases should at the same time be as alike as possible and in the other dimensions. The reason is that when you observe differences between the results of case studies, you want to minimize the possibility that these differences are caused by secondary factors. So if in your case of an oil refinery in Indonesia you were interested in the effect of size, your complementary cases should concern differently sized oil companies in Indonesia. You would not want to look at different sized companies in different countries, because then you would not know if the differences you observe were due to size or location.

In short, your choice of multiple case studies should mimic laboratory research as closely as practical. You should control for as much as possible while examining differences across the factor of interest.

Choice of Case

A final word concerns the choice of case. It is a warning.

The problem is that many people choose a situation for their case study for emotional or other reasons rather than because of the logic of their thesis. This choice is understandable but often has painful consequences for the research and the thesis.

People easily get caught up in a particular case study. They may be natives of the country, have worked in a particular company or branch of government, or

have contacts in a specific situation. These kinds of connections give them confidence with regard to that situation and probably some kind of head start. Fair enough. But these reasons are not intrinsically overwhelming.

Anybody planning to construct a thesis around a case study should resist the temptation to focus their effort on what seems like the easiest place to start. The case study must also be completed and, crucially, must be effective in fulfilling its intended role in the thesis. You must carefully think through what is needed of the case study, examine alternative possibilities, and then choose. The considered, best choice may happen to be the first one intended. However, the choice that was initially obvious may turn out to be undesirable overall, since the data may prove to be inaccessible (a home country may be quite far away), the company may object to one of its former employees discussing its problems, or the situation itself is too particular, too unrepresentative to provide a good test for a theory you seek to demonstrate.

7. CONSTRUCTION OF ARGUMENT

The ultimate point of the research is to substantiate the thesis. Unfortunately, many fail to communicate their results well by either being unaware of, or by not following some fairly elementary guidelines for justifying their results.

The object of this chapter is to present some of the principles for constructing an argument, and thus to help you do justice to your work.

The General Rule

The general rule is to focus on the overall goal. This has two parts: You need to make the point, and you need to eliminate clutter that hides your message.

Make the point: The presentation -- of the whole, of a chapter, or of a figure or table -- should be organized around the point to be made. Other organizations are confusing; overly long and therefore more difficult to follow; and generally relatively ineffective.

Eliminate the Extraneous: It is wiser to omit material if it is not especially pertinent. Irrelevant material is not neutral: it is costly; it is a distraction. Above all, the thesis is not a lab report covering everything that you have read, thought or done. Much -- half or more -- of what anyone does in their research turns out to be beside the point. Not to find what you want when you are looking is a natural part of any research process. It is rarely useful to discuss many, if any, of the dead ends your encountered.

Many of the details which you went to much effort to define, and which are surely interesting in some context, will not really be relevant to the argument, the point you finally decide to make. As you progress in your thesis, you almost certainly shift your topic and redefine its focus, so that much that may seem relevant at the start is no longer useful to the final argument. These details should be dropped from the main text. If absolutely necessary, they can be put into an appendix.

To make your argument well, you need to select what is essential and omit what is tangential. This effort requires a lot of work. Passing from primitive (and ineffective) forms of arrangements -- such as an overall account, a chronology, or a description -- to a real thesis requires much thought. In a phrase: a good argument is constructed through disciplined editing.

Making the Point

To make your point well, you need to discipline your efforts. You should ask yourself in particular:

- Am I being direct about my argument? Will readers follow me easily? Or is my argument "all there, but disorganized"?
- How does this section (chapter, paragraph, figure, table) help me to make my point? Is it useful or a diversion?

As you present a section, whether it is a chapter, a figure, or a table, it is useful to iterate through the following sequence. A number of variations are possible, but his series captures the essential elements.

Define the point to be made: While it may -- should -- seem elementary to know why you are doing something, it is constantly amazing to rediscover how often a writer is unable to define the point of even something so simple as a graph. For an extended section, such as a chapter, it is useful to write a paragraph describing what it is you want to say in the chapter. You may not find this easy to do, and that by itself should be revealing: it means that you do not yet really understand what you are writing about. And if you do not, whom can you really expect to understand it?

Define the audience: The nature of the audience you want to reach determines how you can and should present the material. Operationally, you need to decide:

- What premises do you think your audience starts from/
- How do they see the situation?
- What can you take for granted as basis for building your argument?
- What misconceptions have to be removed?

Outline your positive argument: To validate your argument, you need to make both positive and negative arguments. You need first all to show that your evidence does indeed support your thesis -- this is the positive argument. Complementarily, you need to show that alternative explanations of your results are inappropriate or less satisfactory -- this is the negative argument.

The positive argument is obviously necessary. It also comes naturally to researchers. They are typically immersed in their topic, have gone out to find evidence to support thesis ideas, and know how they will use it to build their case.

A positive argument is not sufficient however. It may be satisfactory to people who want to believe the argument you want to advance, but it will not be enough for skeptics who start with alternative views of your subject. You need to show them that their interpretations do not work as well as yours.

The negative arguments are most important because the skeptics are your prime audience. Although "preaching to the converted" is satisfied -- as you can count on a positive response -- it accomplishes little in terms of building additional support for your ideas. You will be really successful when you convert the skeptics and change peoples' minds. The skeptics are your target audience, and thus the negative arguments, disproving their preconceptions, are vital to your case.

Edit: As you write, you should constantly review your work and, as you do so, revise the product of the above steps. The development of a good argument requires an iterate process of refinement.

Timing

You should begin to write up your thesis substantially before you believe that you have finished the research. This apparent paradox is explained by the consistent observation that you will find out, as you prepare your argument, which you have left out some important elements. This revelation will prompt you to continue your research to cover the gaps in your logic you have discovered. Thus, you will in any case have to continue your investigations after you complete your initial draft. You might as well integrate this phenomenon directly into your work plan.

8. DESIGN OF ILLUSTRATIONS

An illustration is any part of the presentation whose main impact is visual: a graph, a figure, a table, a photograph.

Illustrations can be an extremely important part of your argument. On the one hand they have an immediacy which is powerful ("a picture is worth a thousand words"). On the other hand, many readers will, at least at first, tend to skim a thesis or paper, and retain only a few elements. Good illustrations can reach this element of your audience, as well as reinforce the appreciation of those who will read in depth.

This outlines principles and procedures for the presentation of figures and graphs, work which is notoriously – and needlessly – badly done in practice. These ideas are illustrated by examples. For further guidance, consult:

- Schmid, C.F. (1983) *Statistical Graphics -- Design Principles and Practices,* John Wiley and Sons, New York, NY.
- Tufte, E.R. (1983) *The Visual Display of Quantitative Information,* Graphics Press, Cheshire, CT.
- Tufte, E.R. (1997) *Visual Explanations: Images and Quantities, Evidence and Narrative,* Graphics Press, Cheshire, CT.

Principles of Illustrations

Six principles should be kept firmly in mind when preparing any illustration. These are:

The Organization contains half the information: How the material is presented is as important as what is presented. The organization is the means by which you put the material in perspective. Remember, since as author you are making your own argument, it is up to you to arrange the material so as to make your point most effectively. There is absolutely no need to present the material in the same way as it was displayed in the original source, for example.

Every illustration should have a point: It should enhance a part of the argument you are making. If it does not, it should be eliminated or placed in the appendix for archival purposes.

There should be only one point per illustration: More than one is confusing. Use more figures to make different points. Exceptions to this rule are rarely justifiable.

Illustrations should be constructed to make their point: Extraneous material should be deleted. Key ideas should be given prominent positions. Secondary elements should be kept in the background.

Illustrations should be consistent between themselves: A sequence of Tables of Figures presenting similar material should be organized similarly. Do not reverse axes, use different units, or reorder columns and rows. Doing any of these will confuse the reader, and probably lead to misunderstandings.

Every illustration should be self-contained: You should be able to understand it without consulting the text. There are two reasons for this: one is that it makes the illustration much more powerful; the other is that illustrations are frequently seen out of context.

Procedure for Designing Illustrations

The procedure consists of the following steps:

- Determine the point of the illustration, there should be only one;
- Eliminate extraneous material;
- Organize essential material to make the intended point more clearly;
- Label the illustration to explain all elements clearly on the illustration itself; and
- Caption the illustration, indicating the point intended and suggesting key limitations.

Application of Procedure

To indicate how the procedure works, it is applied to a badly designed Table from a thesis, whose initial version is in Exhibit 8.1. This first version has numerous defects. For one, it is impossible to tell from the illustration what it is about. (It happens to concern a solar energy system.) Secondly, it is not at all evident what the reader is to make of the data. Thirdly, it contains a lot of redundant material (surely it is not necessary to repeat “MWH” 15 times), and absurd meaningless detail (can we really believe that we can measure solar output accurately to six decimal figures, that is one part in a million? And so on.

Exhibit 8.1: **The Table to be revised by the recommended procedure**

Table XYZ: Single System Analysis—Heat Flow Summary

Collector Sub-system		
Collector Output	1420.87 MWH	
Pipe Loss Forward	17.13 MWH	
Pipe Loss Return	20.38 MWH	
Collector Supply		1383.36 MWH
Storage Sub-System		
Storage Loses	378.89 MWH	
Collector Supply - storage losses		1004.47 MWH
Stored Heat Year End - Year Beginning	-20.23 MWH	
Collector and Storage Supply		1024.70 MWH
Auxiliary		
Auxiliary Pump Electric Energy	0.00 MWH	
Auxiliary Heater	1203.94 MWH	
Total Supply		2228.64 MWH
Load		
Dist. Loss Forward	34.73 MWH	
Dist. Loss Return	26.59 MWH	
House load	2167.22 MWH	
Total Load		2228.64 MWH
Ratios		
Collector Supply/Total Load	62.07 percent	
Collector Supply Minus Storage Losses/Total Load	45.07 percent	
Collector and Storage Supply/Total Load	45.98 percent	

Determine the point of the illustration: The Table in Exhibit 8.1 contains what seem to be two different kinds of material: some accounting of energy, and a set of ratios. it is not clear how these data relate to each other. For the sake of the example, let us simply agree that the point of the illustration is to show the reader the relative importance of the elements that constitute the energy balance of some solar energy system.

Eliminate Extraneous Material: Much of the material in Exhibit 8.1 is clearly unnecessary for the point to be made. All those repetitions of “MWH” can go, for instance; there must be a simpler way to show this. Likewise, all those decimal points are meaningless.

Additional material can also be discarded, once we recognize the nature of the data. It refers to measurements of a solar energy system. Measurements on such devices are unlikely to be accurate down to 1%. Consequently, any entry in the Table within that range can surely be taken out, as being within the level of error of the system.

These two sets of eliminations, one obvious and the other based on an understanding of the material, leave us with the simplified table shown in Exhibit 8.2.

Exhibit 8.2: **Table stripped of extraneous materials**.

Table XYZ: Single System Analysis -- Heat Flow Summary

Collector Sub-System		
Collector Output	1421	
Collector Supply		1383
Storage Sub-System		
Storage Losses	379	
Collector Supply Minus Storage Losses		1004
Collector and Storage Supply		1025
Auxiliary		
Auxiliary Heater	1204	
Total Supply		2229
Load		
House Load	2167	
Total Load		2229
Ratios		
Collector Supply/Total Load	62%	
Collector Supply Minus Storage Losses/Total Load	45	
Collector and Storage Supply/total Load	46	

Organize Essential Material: Having reduced the original table to its essentials, it becomes clear that it can be reorganized to good effect. First, there is basically one entry per sub-system. There is thus no need for sub-headings. Second, since the table does not say anything about the load, and since it is trivial to state that "energy provided" = "energy used", we can drop the "Load" sub-heading. Third, it now becomes clear that the ratios refer to the proportion of energy provided by the sub-system. These ratios can thus be placed adjacent to a column of data on the absolute energy provided.

Label the Illustrations: The Table now consists of three columns, whose labels should be clear. One refers to the element that provides the energy, another to the amounts produced, and the third to the proportion produced.

Caption the Illustration: The caption should emphasize the point being made and indicate key limitations. Through the process of elimination and reorganization,

the point no longer concerns the “energy balance” of the system, but the contributions of its components. The key limitation is, presumably, that the data apply to a particular design. Exhibit 8.2 presents the final result of the redesign. This version is focused, and to the point. Being simpler, it is easier to understand, and thus makes its point more effectively too.

Every caption should be self-contained and make the point intended by the illustration. It is common practice, in North America certainly, to place captions at the:

- Top, for Tables and Exhibits, and
- Bottom, for Figures and Photographs.

You should construct Tables so as to avoid repetitions in their headings. Use major and minor headings as necessary.

Exhibit 8.3**: Final, simpler and more effective version of the Table**

Table XYZ: Contribution of Sub-systems to Total Energy Production for Example Solar Storage System

System Element	Energy produced (MWH)	Contribution to Total (%)
Collector	1383	62
Storage Losses	-359	-16
Net Collector and storage	1024	46
Auxiliary Heater	1204	54
Total	2228	100

9. ASSIGNMENTS FOR THESIS STUDENTS

Note: please see the calendar section for assignment due dates

Thesis Formulation

Write a two page description and justification of the formulation of your thesis in five parts:

- Its central question or issue,
- The one or two key methods you will use to test or elaborate this hypothesis,
- The evidence or data available to support your answer,
- The feasibility of your approach within the time and capacities at your disposal, and
- The logic by which you will establish the point of your thesis.

Abstract

First draft a preliminary abstract of your thesis in 300 words or less. It should cover:

- The point of your thesis,
- What you have demonstrated,
- How you did this,
- How you disproved alternative theories, and
- Recommendations.

Now, pull out the lead sentences of each paragraph in your abstract. If they do not summarize the abstract, then it needs to be rewritten.

Time Budgeting

First, prepare a preliminary budget of your time in three steps:

- List the resources (data, facilities, professional skills) you will need for the thesis.
- Identify what you will have to accomplish to acquire these resources; indicate how much time and money are likely to be necessary to accomplish these tasks.
- Draw up preliminary schedule of how all these pieces could fit together realistically. Normally this will suggest some accommodations you may have to make.

Second, use a computer program to develop a preliminary:

- Schedule of the tasks involved in your thesis; and
- Bar chart of the level of effort you anticipate by week to complete the thesis.

Literature

First, draw up a bibliography of the most significant material in your area. This should be in standard form: Last name of author, first name, (year), title of piece, publisher or journal, place of publication if book, otherwise volume number pages.

Then write a two-page report indicating why and how these references represent both the major schools of thought in your area, and the most significant contributors on your topic.

Data Collection

Prepare a two-page report indicating and justifying:

- The evidence you intend to collect to support your thesis;
- Where your data may be found and how you plan to collect them;
- The amount of your time, the cost, and the delays required to obtain the data;
- How you will insure the reliability, validity, representativeness and significance of the data; and
- What you will do to maximize the efficiency with which you collect the data.

Construction of Argument

Step by step, describe:

- The point you are trying to make. Use 1 or 2 sentences at most. Describing your point so briefly is, in fact, much more difficult than using fifteen or thirty sentences to talk generally about the subject. This is part of the point of the exercise, to get you to think hard about what you are really trying to say.
- What there is to demonstrate: You need to specify the distance between the point your thesis is trying to make and what is currently accepted by your audience. For example, if you are writing about privatization to economists you would not have to demonstrate microeconomics. If however, your audience consists of members of a public interest group, you might need to demonstrate why economics is relevant to their priorities.
- The logic you will use to show that your thesis is plausible, that is, consistent with findings of your research (or with other evidence).
- The alternative explanations for this evidence, for example, as generated by alternative political or professional perspectives.
- Why alternative explanations of your findings will be less satisfactory than yours.

Generally speaking, the parts of your thesis that do not relate to these 5 issues are extraneous on the principle that "Less is more," that is that less clutter, the clearer the message, the extraneous parts should be dropped from your thesis.