HANDBOOK FOR INTERACTIVE QUALIFYING PROJECT ADVISORS AND STUDENTS

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PART I

CHAPTER 1

INTRODUCTION
The IQP and the WPI Plan

An Interactive Qualifying Project (IQP) at WPI is a project which deals with the relationship between technology and society. The IQP is a central feature of the WPI Plan, a new approach to engineering undergraduate education introduced at WPI in the early 1970s. The goals of the Plan are to promote learning by doing through project work, maximize student choice in designing their own educational programs, and ensure that students had not only passed courses but were in fact competent as professionals, literate in the humanities and understood the societal implications of their professional work. The IQP contributes importantly to the first two of these WPI Plan goals as well as, of course, the last.

Importance of the IQP

It has been frequently observed that the IQP is the only unique element of the WPI Plan. What is less commonly recognized is that the IQP is of critical and growing importance to WPI's entire undergraduate educational program and our ability to attract students. This importance is due to its uniqueness and distinctiveness and the following major factors:

- The IQP is vital to WPI's claim to have a project-oriented program. Many colleges, including liberal arts colleges, require senior year theses in a student's major discipline. The presence of the IQP doubles our program's commitment to project work relative even to those programs that do involve project work in the senior year. Recent surveys have shown that our emphasis on projects is clearly the most attractive aspect of the WPI plan for prospective students.

- The IQP is the means which WPI has chosen to make science and engineering students aware of the role of their professions in society. The importance of such an understanding has been reinforced by the proposed ABET Engineering Criteria 2000, which requires that engineering programs demonstrate that their graduates have "the broad education necessary to understand the impact of engineering solutions in a global societal context." The IQP is also a very effective means of meeting or helping to meet a number of other Criteria 2000 outcome requirements such as "an ability to function on multi-disciplinary teams", "an understanding of professional and ethical responsibility", and "an ability to communicate effectively".

- The IQP is by design interdisciplinary. Despite the fact
that virtually all real-world problems of broad scope are interdisciplinary, technical education has found no good way to provide students with interdisciplinary experiences. Through their IQP's students obtain practice in dealing with unstructured, open-ended, interdisciplinary problems, opportunities to work independently with peers and extensive experience in writing about previously unfamiliar concepts utilizing new terminology.

- The IQP is the major element of another important pillar of the WPI educational philosophy, that is the freedom of students to make their own educational choices. However, course selections must satisfy distribution requirements and Major Qualifying Projects (MQPs) are frequently utilized to meet the design requirements of engineering accredited programs. Fortunately, in choosing their IQPs, students can truly be guided by their own interests. The ability of students to pursue their own interests is clearly another major selling point of our educational program.

- The IQP is essential for our off-campus programs. It would be very difficult to arrange to have students from a wide variety of disciplines, and concentrations within those disciplines, working together on their disciplinary projects (MQPs) at off-campus sites on a continuing basis. Therefore, we are not likely to be able to build up the level of our off-campus MQP activity to anything more than a fraction of what the IQP permits us to do. Many of the environmental concerns and other issues involving societal/technological interactions that are natural subjects for IQPs are inherently international in character and scope. Consequently, there is a natural synergy between the IQP and Global Programs. Though MQP numbers off campus are growing, it is no accident that almost all of the projects conducted abroad to date have been IQPs.

Perception of IQP Quality

The IQP is obviously very important for our undergraduate program and consequently, its quality has to be an issue of major concern. Unfortunately, we do not marshal all of our possible resources to prepare students for the IQP. For example, there is no specific set of courses or activities required as preparation for the IQP (except to a very limited extent for off-campus IQPs), and there is typically no correlation between students’ social science and humanities coursework and choice of IQP topic. Most observers would assume that the social sciences and humanities have relevant analyses to contribute to an understanding of the relationship between technology and
society and human values. However, it is clear from our program that we are not requiring our students to acquaint themselves with any of that background as preparation for their IQPs. Moreover, we know from our many past reviews of IQPs that even the best projects very frequently fail to apply clearly relevant methods of analysis or knowledge drawn from the social sciences, humanities, mathematics, and other disciplines. Methods of survey research, case studies, content analysis, comparative analysis, historical analysis, cost benefit analysis, statistics, interviewing and modeling techniques, among others, are not being used where appropriate or are being used incorrectly.

We also know that common methods of scientific inquiry (hypothesis formulation and testing) are frequently not brought to bear in IQP's and that, in the past, a great many IQPs, particularly those done on-campus, fell far short of reasonable intellectual standards for college level work. The issue of IQP quality has assumed added urgency recently as a result of our decision to be reviewed for the ABET reaccreditation under their new outcomes-based criteria.

Objectives of the Handbook

The primary purpose of this handbook is to provide faculty with information that will help them do a more effective job of advising IQPs and avoid the quality problems common in the past. The handbook describes the objectives of the IQP; expectations for IQP outcomes; grading standards; issues to be considered in selecting the topic and designing the project, including key problems in project design to be avoided. It provides advice on how to write project proposals, conduct literature reviews, form and manage project teams, schedule project activity; run project meetings, review drafts, conduct assessments, and organize and structure the reports. It defines, describes and illustrates the application of several commonly used methodologies in the social sciences, humanities, management and mathematics that are applicable to IQPs. It is intended to be useful to both faculty and students. Most chapters are clearly aimed principally at the faculty. For others the reverse is true. However, student familiarity with the content of this handbook, particularly the chapters directed at them, will facilitate the advising process.
PART II

IQP OBJECTIVES, EXPECTATIONS AND DESIGN
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CHAPTER 2

THE OBJECTIVES OF THE IQP

THE 1972 ZWIEBEL REPORT

In 1972, a group of seven faculty under the leadership of Imre Zwiebel, Head of the Chemical Engineering Department from 1976 to 1980, formed a committee to define the requirements to be met by the Interactive Qualifying Project. They proposed, and the faculty subsequently approved, that this project must deal with interactions among technology, society and human needs. They supported their recommendation with the following rationale:

"The engineering curricula of the past were primarily concerned with the conveyance of technological skills and scientific concepts. Their primary purpose was to train the personnel needed to design and operate the machinery of a rapidly evolving technological era. Graduates often emerged ill-equipped to assist society in evaluating the overall effects of technology on the quality of life. At this point in the technological revolution, however, it has become increasingly evident that the institutions and value systems of society are strongly related to its rapidly changing technological base. Significant educational reform is urgently needed. That is why the architects of the WPI Plan have established the concept of the Interactive Qualifying Project as a degree requirement. This degree requirement is intended to effect a broader and more integrative education for engineers and scientists.

The Zwiebel Committee expected that "as a result of completing the Interactive Qualifying Project students [would] be

--sensitive to general social problems
--able to question, criticize or reinforce prevailing ethics and value concepts
--aware of societal-humanistic-technological interactions
--able to analyze these interactions
--able to make better judgments and policy recommendations on issues that affect society."

"In the future a graduate will be prepared to stand back, momentarily detach himself from the details of the everyday activities, and observe and assess the ways in which technology and society impact upon each other. It is hoped
that he will also develop a sense of balance and self-confidence, so that he can view the course of events in a context of controllable change and not solely as a threatening, inevitable, and irreversible phenomenon. By understanding the nature of social needs and human interactions he will be able to apply his efforts and energies to effect changes of benefit to mankind. (Zwiebel Report, pp. 5-6)"

Original Objectives of the Interactive Qualifying Project

In their 1972 report the Zwiebel Committee defined the specific educational objectives of the IQP as follows:

1. To create an awareness of socially related technological interactions

2. To enable the identification of socio-technological systems, subsystems, and the linkages between them

3. To cultivate the habit of questioning social values and structures

4. To develop and integrate the skills of evaluation and analysis in the societal, humanistic, and technological disciplines

5. To provide methods for assessing the impact of technology on society and human welfare, and the impact of social systems on technological developments

6. To encourage the recommendation of policy."

The Committee noted that "it is unlikely that every Interactive Qualifying Project will meet all of these objectives.... Working toward these objectives, however, will aid the student in gaining a more mature understanding of himself as a professional whose decisions have human and social consequences. Engineers are being held increasingly accountable for these consequences of their decisions. The Interactive Qualifying Project is the vehicle by which WPI seeks to prepare its graduates to meet this challenge. (Zwiebel Report, pp. 8-9)"

Relevance of the Original IQP Objectives Today

These original objectives have withstood the test of time. If anything, they are even more relevant and appropriate today than when they were originally set out in 1972. The new proposed ABET Engineering Criteria 2000 at last explicitly recognize the importance of the relationship between technology and society, and the need for a global outlook. In Criterion 3, Program Outcomes and Assessment, requirement (h) calls, as noted above, for "the broad
education necessary to understand the impact of engineering solutions in a global/societal context." It is certainly the case, as ABET clearly recognizes, that the issues surrounding the relationship between society and technology transcend international boundaries and are typically very international in character. Consequently, the IQP provides a logical vehicle for globalizing undergraduate engineering education.
CHAPTER 3

EXPECTATIONS FOR IQP OUTCOMES

To ensure that the objectives of the IQP are achieved it is essential that advisors and students share a common set of expectations for the outcome of the project. Ultimate responsibility for establishing appropriate expectations with respect to the level and scope of work done on IQPs rests with the faculty advisors and should, of course, be communicated clearly to students at the beginning of project work. The following discussion is intended to stimulate thought on this subject and help advisors form their own judgments.

As an IQP is intended to be equivalent to three courses, it would seem that there should be little disagreement that the scope of the work expected from each student should bear some equivalence to what would be expected in three courses, and that the level of difficulty and complexity would be comparable to upper class college level courses and would reflect a similar commitment of time, i.e., 15 hours per week. Our experience has shown that to realize these expectations in practice it is helpful if the objectives of IQPs are multifaceted. There may be one overriding objective but it will be possible to identify, at a minimum, sub goals that can be accomplished at different stages of the project or allocated to different individuals. Failing that, the procedures required to achieve the objectives should be multifaceted in the sense of involving numerous steps, and possibly alternative approaches, so that the efforts of the entire project team will be required to accomplish them. Obviously, if adequate expectations have been fulfilled, the advisor will be able to look at the project group's output and say honestly that, yes that output could not have been achieved with one or more fewer students.

Experience has also shown the importance of good literature reviews. A topic of substance that is suitable for a college project degree requirement is likely to be one which has attracted the attention of prior investigators. It is very important for students to become familiar with the relevant literature in order to immerse themselves in the topic and to ensure that their work will benefit from knowledge of what has already been accomplished. The literature review should demonstrate that the students have been able to interpret the published prior work for themselves and that they understand its implications. The literature reviews of our best projects are thorough, and suggest that the students have in fact acquired significant mastery of an identifiable field of inquiry.
The project report should have a structure that is appropriate to the topic. The structure employed at many of our off-campus project centers provides a useful framework that can be of benefit, particularly in helping to organize the research and in suggesting aspects that should be included. That structure includes the following sections:

- an abstract and executive summary
- a background section outlining the general nature of the subject under investigation;
- a statement of the specific objectives of the project;
- a literature review as discussed above;
- a methodology section outlining how the project's objectives were achieved;
- a section presenting the results of the research, which would describe any data, survey results or experimental results that have been obtained;
- analysis of the results, and conclusions drawn from that analysis;
- and finally a set of recommendations for policy actions or further research based on the conclusions.

In a given project, some of these sections may be much more important than others, and some may not be appropriate at all. The final report structure will reflect that relative importance.

The writing should be at a professional level: clear, well organized and free of spelling and grammatical errors and awkward expressions.

The methods of analysis utilized in the project should be appropriate to the topic and reflect the practices of other researchers who have conducted similar investigations. Where a given type of analysis is clearly feasible and appropriate, it should be conducted, and conducted correctly whether it involves statistical analysis, cost/benefit analysis, life cycle costing, survey research or any other technique.

It is of course, important to remember that IQPs must be interactive in the sense that WPI has defined i.e. they should examine "how science or technology interacts with societal structures and values". More specifically IQPs should meet one or more of the educational objectives, originally identified by the Zwiebel Committee in 1972 and presented above in Chapter 2.

Finally, there is the issue of the length and size of the project report. It is axiomatic to say that the number of pages of a report is not the primary determinant of its
quality. Moreover, we wish to encourage students to write succinctly, as well as clearly and certainly wish to discourage them from padding reports, particularly with material copied from other sources. However, if students are to do a thorough job of surveying the literature and describing the multiple steps that they have followed to achieve an objective of some complexity, the result is quite likely to be a report of significant length, far longer than a term paper for a single course, closer to the thirty or so pages per student average achieved by our best projects than the dozen or fewer pages common in the past for the shortest and weakest project reports. It would seem that the appropriate model for IQPs would be that of a thesis or a professional report to a lay audience that is unfamiliar with the literature. Such an audience could not only benefit from a thorough description of that literature, but will require a detailed explanation of the analytical techniques employed and the steps followed to conduct the analysis, to reach conclusions and to make recommendations. An alternate model, that of a journal article addressed to an expert audience already familiar with the literature, not requiring all steps of analysis spelled out in detail, and looking essentially just for the new knowledge provided by the research, would hardly seem to be an appropriate model for undergraduates who are typically not even majoring in the disciplines involved in the study.

Advisors should, logically, require that projects meet their expectations adequately to receive a passing grade and meet them in an outstanding fashion to receive a grade of A. Their grading standards could should conform to those adopted by the faculty in its Resolution on Project Grading Adopted on May 5th, 1994 and presented below in the appendix to this chapter.
Appendix

Guidelines for Project Grading

Approved by Faculty on May 5, 1994

Background
Pronounced grade inflation for MQP, IQP, and Sufficiency activity is evident over the last twenty years. This has, in turn, resulted in a steady increase of the percentage of students graduating with honors. Furthermore, data indicate that project grading standards vary considerably from department to department. This not only creates an inequity with respect to honors, but may create barriers to student or faculty participation in multidisciplinary project activities.

Recommendations
Each term a student is registered for a project, the student receives a grade reflecting judgment of accomplishments for that term.

Upon completion of the project, students will receive an overall project grade. It is important to note that this grade reflects not only the final products of the project (e.g., results, reports, etc.), but also the process by which they were attained. No amount of last-minute effort should turn a mediocre project effort into an A.

The available grades and their interpretations are as follows:
* A: a grade denoting a consistently excellent effort which attains the stated project goals.
* B: a grade denoting a consistently good effort which attains the stated project goals.
* C: a grade denoting an acceptable effort which partially attains the stated project goals.

* SP: a grade denoting an effort sufficient for the granting of the credit for which the student is registered. This grade provides students with no feedback, and its use is discouraged, except for circumstances in which the faculty member is unable to judge the quality of the work (yet can still determine that the granting of credit is appropriate).

* NA: a grade denoting an effort unacceptable for the credit for which the student is registered. Note that this grade is entered into the student's transcript.

* NR: a grade denoting an effort insufficient for the
credit for which the student is registered. This grade is appropriate when the project has not proceeded due to circumstances beyond the control of the student, or for project extensions which do not represent the full amount of credit for which the student is registered.

The results of a project should be such that an outside reviewer would reasonably deem the project as being worthy of the credit and grade given, based on evidence such as the project report.

In light of the above grading criteria, it is strongly suggested that a formal project proposal or contract be developed early in the project activity, so that all participants in the activity have a clear understanding of the project goals and advisor and student expectations. [It is worth noting that many faculty communicate their expectations to students in the following form: to qualify for an A a project must exceed established expectations, for a B a project must meet established expectations fully, and for a C a project must satisfy established expectations.]
CHAPTER 4

THE INTERACTIVE QUALIFYING PROJECT: SELECTION AND DESIGN

The Interactive Qualifying Project (IQP) at WPI is an undergraduate degree requirement which is equivalent to three courses and is normally completed by students in their junior year. The IQP is designed to address the societal impacts of a technological development or the converse. It may involve investigation, analysis, description, and/or forecast of such an impact or the design of policies to cope with the societal problems (or to take advantage of the opportunities) created by technological change. In the course of doing their IQP, students are expected to achieve at least some of the following educational objectives: become aware of the many important links between technology and social systems; learn to question existing social values and mores; learn to integrate the skills of analysis in science, engineering, social science and the humanities; and assess the impact of technology on society and the conditions of human life.

Types of Projects

The following types of projects are representative of those that have been found in the past to satisfy the goals of the IQP. These categories do not exhaust the list of possible topics. Moreover, some of them are overlapping and many projects will fit in more than one category. (The IQP divisions listed in the undergraduate catalog to which these categories most closely corresponded are indicated in parentheses)

1) Technology Assessment Projects examine the impacts of technological change on economic growth and development, occupation and the work place, our social and political institutions, and health, safety and the environment. These projects may focus on the impact of specific technologies on specific groups or look more broadly at how technological development affects the economy and society in general. (Divisions 41, 43 and 49)

2) Studies of the Societal Determinants of Technological Change examine the social and economic factors that influence the rate of invention, innovation, transfer, and diffusion of new technology. Projects in this category may also address the social, economic and technical feasibility of specific new technologies. (Divisions 46 and 49)

3) Projects on Science and Technology Policy focus on the policy issues that arise from the government's role in supporting research on science and technology and how society makes collective choices about the development of technology through the political process. Projects may also
consider the political issues surrounding the international transfer of technology, and technology policy within private firms: R & D management, intra and inter firm technology transfer and corporate technology strategy. (Division 45 and 46)

4) Projects in Law and Technology focus on the interaction between legal and regulatory institutions and technology. Project students study statutes and their history, regulatory systems, administrative decision making, and judicial decisions to determine their impact on technology. In addition, students study the operation of technology in a legal environment to determine whether social goals expressed in laws are realized in practice, i.e. Will the Clean Air Act clean air? Aspects of legal and regulatory decision making are also studied. For example, when do courts accept scientific evidence as determinative of facts in product liability cases and legal challenges to regulation? (Division 52)

5) Projects on Technological Issues in Public Policy examine issues where the pivotal questions on which a public policy decision depends require answers that are heavily technical in nature. An example would be the nuclear waste disposal problem, where the critical issue is whether or not it is technically feasible to isolate nuclear waste from the environment. These kinds of policy decisions tend to depend on assessments of environmental impact, effects on health and/or mortality and risk. They may also require considerable knowledge of pertinent laws and regulatory practices and involve the evaluation of existing regulatory schemes. (Divisions 41, 47, and 52)

6) Science, Technology, and Society (S.T.S.) studies emphasize the critical examination of conventional wisdom about the social implications of science and technology, and question the assumption that technological advances automatically represent social progress or that technology impacts society rather than vice versa. (Division 46)

7) Humanistic Studies of Technology focus on the interaction of science and technology with the humanistic and non-quantitative aspects of culture. These projects can range over an enormously broad area to include such diverse topics as the relationship of literature to technology or science and philosophical analysis of the nature and role of the individual in a high-level technological society. (Division 48)

8) History of Technology Projects examine the effects of past technological developments on the evolution of our society and culture. These projects may be conducted at museums where students work with professional staff, documents, and artifacts to gain a unique understanding of
the past and present. (Division 48)

9) Technological Solution Projects explore ways in which new technologies can be harnessed to address social ills and their effectiveness at ameliorating specific societal problems.

10) Projects on New Technologies for the Delivery of Health Care, Social Services and Education: These projects examine the potential of new technologies to improve services and the economic and ethical issues which technological developments create. Many projects in this area will be concerned with the strengths and deficiencies of the systems which the private and public sectors of our society have established, or are proposing to establish, for dealing with community problems. (Divisions 43, 50 and 51)

11) Urban and Environmental Planning Projects offer the student a wide range of opportunities to investigate and analyze problems that require a systematic and comprehensive approach to planning. The topics cover many different areas, including: environmental analysis, environmental impact statements, resource management programs, redevelopment and renewal of city neighborhoods, preservation of agricultural lands, conservation and open-space and land use planning, demographic policies and community facilities planning, and impacts on infrastructure development. (Division 44)

12) Projects on Resource Use and Supply are concerned with the technological alternatives for meeting society's resource needs, the economic, environmental, and human value questions that must be faced in choosing among these alternatives, and the role of our social systems and institutions in determining the choices that are made. These projects often examine the economic feasibility, the environmental side effects, and the impact on public health and mortality of various resource technologies and alternatives. (Division 42)

13. Projects on Gender, Race, and Technology generally research issues in two areas: (a) the participation of women and people of color in engineering and science education and in the engineering professions, and (b) the effects of particular technologies on women, African-Americans, Hispanics, Native Americans, and other specific racial or ethnic groups. However, these projects may also examine such topics as ethnic diversity in the technical professions, the attitudes of engineering students toward cultural diversity, and the experience of women in the sciences.

14. Projects on Technological Literacy and Public Understanding of Science examine such issues as the public
perception of science, the role of an effective citizen in a technological society vis-a-vis the socially concerned technologists or scientist, and what the public needs to know and how they should relate to the experts in the quest for a democratic yet technological society? Studies of scientific paradigms and their evolutionary and sometimes revolutionary changes over time would fit in this category as would the public perception of unorthodox ideas in science. (Division 46)

15. Technological Forecasting Projects examine and/or apply the various techniques available to forecast the development of new technologies and rate at which new products and processes penetrate markets and replace existing alternatives.

16. Historic and Artistic Preservation Projects examine the value and policy issues surrounding decisions on which historic and artistic objects such as buildings, battlefields, statues, monuments, prints, drawings, paintings, and sculptures should be preserved and how best to preserve them. They may also deal with the technical issues involved in art conservation and restoration.

The categories described above can serve as effective guidelines in designing an appropriate IQP topic. If a project's design corresponds to the description of one or more of the sixteen general categories outlined above, it is likely to have meaningful technology and societal aspects, and to meet at least some of the goals of the IQP.

The Determinants of IQP Quality

Since 1976, IQP reports have been reviewed by faculty, generally on an annual or biennial basis. These reviews have shed considerable light on the factors that influence the quality of IQP outcomes. Our accumulated experience shows that project quality is heavily influenced by the following: the scope of the literature review, location (whether the project was conducted on or off campus), team size (one or larger than one), the number of IQP goals addressed, the balance between society vs. technology, the size of the report as measured by the number of pages in the main body, and the number of analytical methods employed. In the most recent report on these annual reviews, that for 1997, a multiple regression of project quality on all seven of these factors revealed a very high statistically significant relationship between overall project quality and each of them, so high, in fact, as to indicate a virtual one hundred percent probability of a positive relationship. These findings indicate that each variable has a definite impact on quality, even after account is taken of the
influence of all of the other variables. They show that when projects deal with both societal and technological issues, achieve several IQP objectives, and employ recognized methodologies, they tend to be complex multi-faceted projects that involve intellectually challenging work on the part of the students and a substantial amount of writing, and for all of these reasons are judged to be high in overall quality.

The use of recognized analytical techniques in IQP work is very important. The past reviews have checked for the use of the following analytical methods: participant or natural observation, interviews with experts, focus groups, case study, content analysis, comparative research, historical analysis, experimentation, survey research, risk analysis, statistical analysis, investment decision analysis, life cycle costing, modeling, and simulation. They have found frequent use of these techniques. The average rating for overall project quality for projects making no use of recognized analytical techniques has been much lower than for those projects that did.

The results of the past reviews of IQPs have demonstrated that successful IQPs require the following:

1. Topics that are chosen explicitly for their suitability for achieving the IQP objectives and to insure that both technological and societal aspects are represented and ideally are 'real life' projects conducted with off-campus agencies. (As our off-campus IQPs generally are.)

2. Team sizes of two or three students -- in contrast to one person, isolated projects.

3. The preparation by students of careful project proposals -- as opposed to just 'diving in'.

4. Thorough and extensive literature reviews of topics which challenge students to search out existing literature rich in material which elucidates the complexities and multiple possible solutions to real problems.

5. Problem analysis, hypothesis or model testing, the framing of conclusions and recommendations -- instead of the mere recording of daily experiences uncritically; and, of course, explicit attention to the correct application of recognized methods of analysis, such as the sixteen mentioned above.

6. Final reports which contain the essential sections a professional reader expects, from abstract and introduction, through conclusions, references and
bibliography, and appendices (as relevant to their topic).

7. The kind of close attention to all phases of the development of the project, characteristic of the work done off-campus.

Problems to be Avoided in IQP Selection and Design:

From the definition of the IQP and description of the types of projects given above it is clear that the boundaries of good IQP design are very broad. Consequently, it is important for students and faculty to know what types of activities are inappropriate for IQPs and likely to result in weak projects. Our past experience indicates that the problems encountered with the IQP frequently result from poor IQP selection and definition at the outset.

Our worst projects are often on inappropriate subjects. Many appear to have been chosen by faculty or students in the pursuit of a special interest that is inappropriate for, or at least poorly suited, to the design of an IQP. That special interest may involve low level assistance with the faculty's research, developing a teaching aid, or service for an agency with which the faculty member or student has a link. The project topics seem frequently to result from the advisor or students asking the wrong question: that is "how can I/we use the IQP to pursue a particular interest" rather than "how can I/we use our interests to develop a well designed project that is truly an IQP and meets its objectives."

The most serious of these past design deficiencies fall into two broad classes: The first and by far the most serious category are problems that result in projects that are simply unworthy of college credit. The projects in this category involve activities that are not normally part of college programs and do not make the kinds of intellectual demands on students that are traditionally expected of college level work. The second broad class of problems consists of those that prevent projects from achieving the special objectives of the IQP that distinguish it from our other degree requirements. Often these projects have a narrow focus and lack the interaction between technology and society that is at the heart of the IQP.
Not College Level Work:

Projects which fail to result in college level work come in a variety of forms but they share a common feature. That hallmark is a focus on a simple intellectually undemanding activity to the virtual exclusion of the reflective processes commonly identified with college study and report writing. Projects of this type are characterized by a failure to demonstrate an understanding of complex social and technical problems or systems, to analyze cause and effect relationships, to evaluate alternatives, to apply basic principles and theories to problem solving, or to develop policy recommendations.

How to Projects: An example of projects in this category that was common in the past was the preparation of "how to" manuals. Many of these manuals were aimed at the homeowner and offered advice on practical arts at the tradesmen level. These manuals typically consisted of uncritical compilations of facts that are available from existing manuals and reference books. It is theoretically possible that the preparation of a manual (particularly on a complex subject) could be an intellectually demanding task that would serve the aims of the IQP. However, in our past experience it rarely has. That failure is no accident. The basic aim in preparing a "how to" manual is, after all, compiling facts. Analysis tends not to be an inherent part of the process and is often avoided.

Data Gathering Projects: Another example of unacceptable projects are those that ostensibly deal with substantive issues, but in fact never progress beyond the data gathering stage. In many of these projects, students conduct surveys and merely tabulate the results without making any attempt at evaluation or drawing conclusions.

Community Service Projects: The most numerous types of projects involving activities that are inappropriate as degree requirements for engineering students are those that are limited to the actual provision of some type of community service, such as unsupervised practice teaching or assisting the handicapped. Projects focused on these activities are but examples of a class of experiential projects in which the principal weakness is that the students have failed to reflect upon their experiences or to place them in a conceptual context.

"Term papers:" The final category of IQPs that are undeserving of college credit are projects whose principal failing is that their scope and objectives were too limited for the team size and/or the quality of the work that went into realizing these objectives was very low, not college level. The objectives may be appropriate for IQPs, and meet
the aims of the IQPs as far as they go. These projects would typically have been satisfactory if they had greater scope, or if the quality of the literature review, data gathering and analysis had been adequate. IQP reviewers characterized these projects in the past as "term papers" or even "high school term papers"

It is possible for "how to", practice teaching, or community service projects to incorporate analytical or critical components. For example, teaching could involve curriculum development, accompanied by careful review of literature relating to the subject matter and the population to be taught, analysis of learning outcomes, and of the relation of the teaching experience to learning or development theories. In creating "how to" manuals, the emphasis may be placed on the evaluation of alternate procedures to determine whether they will achieve their designed purposes, or which will be best, cheapest or safest. Nevertheless, our track record with these types of projects has been very discouraging. Faculty should avoid them or approach them very carefully with explicit emphasis on designing in the evaluation and analysis of societal impact. Our desire to give students wide discretion in their choice of IQP should not be used as an excuse to allow them to pursue activities that are unworthy of college credit.

**Purely Technical Projects:**

The second broad category of problems that have been identified in past reviews are those that, while not leading to work inappropriate for college credit, do prevent projects from achieving the special objectives of the IQP. Of most concern are MQPs masquerading as IQPs. These are projects that are entirely technical in nature. The "societal" aspect exists only in the sense that the work of professional engineers generally impacts society. Our failure to eliminate completely the phenomenon of IQPs that are really MQPs may reflect confusion in the minds of some students and even faculty as to the nature of the interaction that IQPs require. IQPs are, of course, concerned with the interaction between technology and society. Interacting with other people or agencies, working with off-campus social or benevolent institutions, or working with faculty and students outside one's discipline, while desirable, do not in themselves make projects interactive.

In the early days of the Plan when the IQP was in the process of being created, there was substantial disagreement as to how it should be defined and what its precise objectives should be. In the end, it was agreed that both technology on the one hand, and society and human values on
the other, should be defined as broadly as possible. Nevertheless, there was universal agreement that the project had to embody a concern for the impact of technology on society in some sense. It could not consist simply of a technical design problem. This meant that projects that focused on, for example, developing and designing an aid for the handicapped could not qualify as IQPs simply because of the benefit for which the device was intended. This prohibition has been respected up to the present. Today, IQPs hardly ever involve simply the design of a device where the project is concerned solely with the engineering design problem in a fashion that would make the project virtually indistinguishable from a mechanical engineering or electrical engineering MQP. However, some IQPs deal with other types of design problems, excluding electromechanical devices but, nevertheless, involving a focus on technical design considerations to the virtual exclusion of any kind of analysis of the societal impact. This is particularly true -- in fact in the past it has been almost universally true of education projects. In this respect, there is no difference between a project which deals with the technical problems of utilizing new computer multimedia technology to provide classroom instruction, and a project which utilizes the latest developments in science and engineering to design a new device for the handicapped? In both cases, the concern is with the application of the new technologies. The project is essentially technological in character.

There is nothing inherently wrong about either type of project as an intellectual exercise appropriate for a college program. However, neither is interactive in the sense of examining the relationship between technology and society. Neither meets the aims of the IQP as originally defined in the early days of the Plan, and neither would help WPI meet ABET's requirement for demonstrating that our students understand "the impact of engineering solutions in a global/societal context."

Education Projects: In general, the education projects have frequently involved applications of technology in the classroom, development of new curricula, and, as noted above, the actual delivery of educational services by our students in the classroom, i.e. practice teaching. An educational project that deals with curricular development could very well be very interactive in nature, if the project delves heavily into issues of the impact of the curricula on the educational process and hence, society, or examines society's educational needs. These kinds of questions do get raised in education projects, but in the past, all too rarely.

Web Page Design Projects: A number of other types of projects have similar problems. Of particular concern currently are projects on designing Web pages. To be
acceptable as IQPs these projects should make appropriate assessment mechanisms a part of their methodology from the beginning. Additionally, surveys or focus groups should be employed to determine the best sorts of information to include, the most effective formats, and the users' special needs before design commences.

The best approach for dealing with all of these types of design projects is to avoid them, -- unless both faculty and students are prepared to consciously incorporate evaluation and analysis of societal impact into the project's objectives from the beginning.

Purely Societal Projects:

At the other end of the society-technology spectrum are projects that resemble humanities sufficiencies or social science MQPs and contain no technical component. Such projects could fulfill some of the aims originally envisaged for the IQP, for example, learning about social values and systems and methods of analysis in the humanities and social sciences, etc. Nevertheless, pure social science or humanities projects clearly fall short of the ideal in that they ignore the society-technology interface. These projects frequently examine a societal or ethical issue that does not involve technology in a central or leading way. In focusing on the aspects of primary concern, technical side issues tend to be ignored. Given the importance of helping students understand the role of technology in our society, it may often be appropriate in these projects to explore fully whatever technical issues do exist, even if this involves a detour from the principal thrust of the project. Moreover, purely societal issues have often received much attention from social scientists. Given the weak social science backgrounds of most of our students and frequently of the faculty advisors, focusing on such issues may not do much more than give the students an opportunity to demonstrate their ignorance.

Maintaining Balance between the Technological and Societal Aspects:

In some instances, lack of balance between technical and societal issues results from the narrowing of a project and from broad and general concerns to a specific "researchable" question. The general issues may provide an ideal example of a problem with multiple interactive dimensions. However, creating a manageable project on a topic often requires narrowing the scope to a sub topic that has only technical or societal aspects. There is no fully satisfactory solution to this dilemma. Given the complexity of the general problem and, often, the intensive research in all
aspects by experts in each field, failure to narrow the project's scope will lead to little more than a literature review. If the identification of a specific researchable hypothesis results in a project that considers only the technical or only the societal aspects of a multi-dimensional problem, some effort should be made to demonstrate that the authors had considered the broad implications. IQPs should address societal/technological issues and the relationship of the particular project to those issues should be clearly identified.

On the other hand, if the scope of the project remains broad and the result is a literature review, the student should strive to evaluate and integrate the findings of other studies and demonstrate a thorough understanding of the subject. Our past reviewers have noted that a common weakness of many literature reviews is that they are often unoriginal, deriving themes uncritically and directly from two or three major authors. Many students seem to think that a discussion mixed with critical comment will be sufficient. Often, however, the critical comment has no credible foundation and it is merely a repetition of someone else's views. There are no obvious criteria for evaluating the evidence, and conclusions are therefore developed on the basis of subjective impressions. In analyzing social and moral issues students are too often captured by a single perspective and too often accept conventional wisdom uncritically.

Assessing the societal impact of technology obviously comes far less naturally to almost all faculty and students than dealing with the technology itself, or a technical or liberal arts subject falling within their areas of expertise or majors. This is often true, at least to some extent, even for social scientists, as the societal impact of many types of technology have not been systematically addressed by these disciplines and the normal methods of analysis in the social sciences may be inapplicable. However, difficult as it may be to address human value issues and the societal impact of technology, that is what IQPs must do if they are to realize the objectives we have set for them, and if the IQP is to serve effectively as the primary means by which WPI satisfies ABET's concerns for insuring that students understand the societal impact of their professional work.
PART III

BEGINNING THE PROJECT

Experience has shown that carefully prepared project proposals and thorough literature reviews are virtually essential to successful project outcomes. Consequently, it has become the norm for work on projects at WPI to focus initially on those important phases of project development. Proposals and even literature reviews for off-campus projects are largely completed during a 1/6 or 1/3 unit PQP prior to going abroad while the entire first term of work on on-campus projects is normally devoted to their preparation. This section of the IQP Handbook contains two chapters providing advice to students on how to write project proposals (Chapter 5) and how to conduct literature reviews (Chapter 6).
CHAPTER 5

HOW TO WRITE A PROJECT PROPOSAL

Lance E. Schachterle

Why a Project Proposal?

Writing a good proposal is a very important tool for organizing time and resources to complete a project which fully realizes its objectives. Whether the proposal is done as a PQP for credit separate from the one-unit project, or as the first fraction of credit towards the one-unit requirement, a project proposal will be invaluable in structuring the students' ideas about carrying out their research and writing their conclusions. Some faculty use it as an informal "Contract" to establish an agreement about the content and limits of the final project report. Also, since the project proposal is a widely used communications tool in the professional world, students will have the advantage of learning what goes into a proposal as part of their undergraduate education.

At WPI, only those students who present budgets in conjunction with a project proposal will be considered for funding toward IQP expenses. Students should consult with their advisors in framing a proposal and a budget, and some modification of these guidelines may be needed to accommodate their subject. But since money for proposed budgets will be allocated competitively, they should be sure to cover the basic points outlined here.

Basic Sections of a Proposal

In addition to specifying the needed allocation of resources to complete the project, proposals have three major sections:

1. Introduction
2. Literature Review (or Background)
3. Procedure (or Methodology)

The "Introduction" tells the reader 1) what the project is about, 2) why the project is worth doing, and 3) why the project is a good topic for fulfilling the objectives of the degree requirement. The Introduction must also state clearly and completely the specific objectives of the project— in some detail, what the students intend to
accomplish. Though the reader encounters it first, the
"Introduction" should probably be written last since the
other parts of the proposal will have to be mastered to
provide an effective "Introduction." The "Literature Review"
tells the audience (advisors, off-campus sponsors, or
sources of funding) what the state of the art in the topic
is. The "Literature Review" should probably be tackled first
since mastering it will provide the background needed to
write other sections. The "Procedure" (also called
Methodology) lays out the method that has been selected to
cannot conduct the research. The "Procedure" should emphasize how
the particular interactions between science, technology and
society will be analyzed and how the research plan will
enable the project to be completed successfully.

A good project proposal has an additional advantage; with
appropriate revisions, the chapters in the proposal can give
students a start on similar sections for the final report.
Good work on the proposal has two advantages: planning for
effective resource use when doing the project, and getting a
jump ahead on the final report.

We suggest that the three sections of the proposal be
written in this logical sequence: Literature Review,
Procedure, Introduction. These guidelines will thus follow
that order. Other material which should go into the report,
and will be discussed below, are the
1. Abstract
2. Title Page
3. Table of Contents
4. Footnotes
5. Bibliography

Literature Review (or Background)

To show their advisor that they know what they are talking
about concerning their project, students need to demonstrate
that they know the background and context of their topic.
Good questions to answer in this section are:

1. What kinds of research have been done before (including
   previous IQPs and MQPs which can be accessed through the
   reference desk at the library)?

2. What relevant kinds of studies or techniques need to be
   mastered to do the project?

3. Where is the state of the art today?

4. How have others gone about trying to solve problems the
   project team wants to tackle, and in what ways will their
   approach build on and vary from previous work?
The background section should be thought of as the place where the most important books, articles, or any other kind of source materials for the project are identified and discussed. To bring another student up to date on what is being done, what would be the most important thing to read? A well written review will provide a sense of critical issues and debates which form the background for the students' own original work.

Everything in the literature review should be mentioned in the bibliography, BUT not everything in the bibliography is important enough to be mentioned in the literature review. In other words, this section is a comment on the most valuable material that has been identified which will need to be assimilated to do the project. The literature review thus provides a guide to all material listed separately as footnotes or bibliography.

Procedure

The procedure or the methodology is the heart of the proposal because it must tell the reader how the students' propose to carry out their project. It must convince their advisor (or in industry their manager or potential client) that they clearly understand their task, have a logical time plan for solving the problems, and have identified all the resources needed.

As the proposal is for an IQP, the project team must take special care to explain HOW they plan to relate some aspect of science or technology to society. Note that "technology" need not be defined narrowly here: "technology" can mean the techniques used to manage or evaluate any resource efficiently, not just "nuts and bolts" hardware. But the students must explain clearly how their procedure insures that the WPI IQP degree requirement will be satisfied by completing a project which defines, investigates, and reports on a topic relating science or technology to a social need or issue. In short, why is the topic an IQP?

Some of the other questions the reader will expect to be answered in this section are:

1. What are the tasks and sub-tasks identified to achieve the objectives?

2. What materials will be needed to carry out the project: equipment? computer support? typing? graphics? others?

3. What data are needed for the project and how will they
be collected? If the project requires a survey or interviews, the design of this instrument (especially the selection of participants) must be explained and justified.

4. What method or process will be used to analyze this data and where else (if anywhere) has this method or process been used?

5. What time frame will be needed to accomplish the identified tasks or sub tasks? Project schedules may be presented in standard forms like PERT or Task Charts?

6. If the students are working on a team, which teammates will accomplish which sections?

7. What costs is the project anticipated to incur—in other words, what is the budget? (A Budget Summary Request Form must be submitted to the Interdisciplinary and Global Studies Division Office as shown in Appendix 1 for IQP Proposals.

Introduction

The Introduction will be the first major section the reader encounters, so it must be made as effective as possible to encourage further interest. The Introduction states the broad problem objectives as well as the project's specific goals, helps introduce the project subject, and explains why the problem is worth solving and who will be interested in the solutions. If the proposal is being prepared for an off-campus project sponsor as well as an advisor, the value of solving the problem must be made clear to the real-world sponsor.

Some questions to cover here are:

1. What is the project subject?
2. What are the goals of the project? the sub-goals?
3. Who is the project audience who wants to use the results: the students? the advisor? off-campus or community groups?
4. How and when will the results be presented physically?
5. How will the results be used?
6. What is the general method or procedure being used to conduct the project?

Other Sections: Finishing Up

Once these three main sections are well along, several other sections coming at the beginning and the end should be drafted to provide the opening and closing expected in professional presentations. These sections are listed below and placed in the order they will occupy relative to the
three main sections noted in parentheses:

Title Page
Abstract
Table of Contents
(Introduction)
(Literature Review)
(Procedure, including Budget)
References--Footnotes and Bibliography
Appendices

Title Page
The title page should contain, neatly arranged, the following: title of the project, project registration, number of the project, name(s) of the author(s), name of the faculty advisor(s), name of off-campus sponsor, if any, and date of submission

Figure 3 shows a sample title page.

Abstract

The abstract should be a brief statement of the topic, procedure, and the projected outcome of the project, in three or four sentences. The abstract of the final report (which can be modified from the one in the proposal) is crucial since it goes on the students' transcripts and is circulated widely off-campus. (The final project report abstract should be about 80 words to accommodate the space on the transcript. It should be made as good as possible since project abstracts are a major source for job interviewers use to formulate questions.)

A three-sentence abstract might well follow this order.

1. First sentence introduces the project topic, mentioning (if relevant) the off-campus agency with whom the project is being done.
2. Second sentence indicates what material will be examined and procedures employed to carry out the project.
3. Third sentence indicates the anticipated conclusions (or results, application, or real world use of the project).
An example:

This proposal, prepared for the U.S. Small Business Administration in Washington, will describe Flexible Manufacturing Systems (FMS) and assess their impact on small businesses. Working from literature and interviews, we will describe FMS technology, its use in industry, and its impact on small businesses especially suppliers. We will assess: 1) if FMS can be used in small businesses, 2) how FMS will impact on small businesses, and 3) if management techniques related to FMS will affect small businesses in the near
future.

Table of Contents

The table of contents lists (with final page numbers) the location of each separately titled section of the report, usually following the sequence above from abstract through appendices. To the professional reader (who as such is faced with lots of reading and appreciates conveniences), the table of contents also indicates at a glance what material is covered.

References

References usually consist of footnotes and a bibliography. Footnotes may appear a) at the bottom of the page, b) at the end of the chapters, or c) at the end of the report but before the appendices. Footnotes usually cite appropriate sources of information (including interviews or verbal contributions from others) or occasionally indicate cross-reference to additional material. The form of the note varies with the professional area concerned, so students should check with their advisor. The standard for such matters is the latest edition of Kate Turabian's A MANUAL FOR WRITERS. Whatever the format, footnotes contain the name(s) of the author(s), book or journal title, date of publication (usually with the place and publisher for books) and, for journals, the volume and page numbers.

The bibliography lists all materials cited in notes. Its value as a list of relevant materials often makes it useful to consult independent of the report itself (therefore, bibliographies in sources should be checked for relevant materials.) Bibliographies are often used as the sole source for the full reference for footnotes; the footnotes very briefly cite the work in question (by author(s) and year, for example), leaving the full citation to the bibliography.

Appendices

Appendices (singular, appendix) contain materials too lengthy for inclusion in the text, or not directly relevant. Certain kinds of raw data, background materials, and the like go here. ALL material in appendices must be referred to in the text directly so readers know why they are here.

Other parts.

Occasionally a proposal and more often a report will contain an Executive Summary. This section, which comes after the abstract, provides a succinct overview of each section of the entire document in five to ten pages. Executive
summaries are required in professional reports, and at WPI, as a part of applying for the President's IQP Award.

A Letter of Transmittal is normally affixed before the title page if the proposal or report is being submitted to an off-campus liaison. This letter is in business-letter format, and tells the recipient briefly that the attached proposal is being submitted as part of an agreed-upon plan to conduct the project with the agency the liaison represents.

Appendix 1 (Budget)

The Budget Summary Request form on the last page should be copied and used to submit a budget request. The following should be noted:

Under item 4, on a separate sheet the project costs should be broken down carefully by itemizing all anticipated expenses. Information supplied on actual costs (such as copies of list prices, estimates, and the like) is crucial in determining accuracy of anticipated expenses. The more information that can be supplied on such expenses as travel, labor, supplies and material, and so on, the better the proposed budget will be.

Travel expenses will be paid per term using the standard WPI travel expense form, signed by the students and their advisor (who thus validates the accuracy of the travel costs.)

Under item 6, the students must contribute from their own funds at a standard rate of $15 per student per 1/3 unit of activity (in place of expenses for books.)

All telephone calls should be placed through the Projects Phone in the Project Center. Costs for calls to destinations within the continental U.S. thus should not appear on the budget, since the support is already available automatically. If an need to make international calls is anticipated, this request should be documented very carefully.

The project students are responsible for all costs normally associated with producing the final report which goes on file at the library, as well as for any copies made for themselves. Reimbursement of standard typing, laser printing, or photocopying costs of the report should not be included in the budget. Others who want copies should pay for their copies.

Requests for support ALWAYS look better if the students indicate that they have investigated all possible avenues, and have identified funding sources (off-campus agencies,
research grants) in addition to what they are asking from the IGSD Office or your department.

Under item 8, briefly describe the project's objectives and procedures (to enable the committee to weigh this request relative to others.)

Bibliography

Other useful books and guides:
Any good college dictionary
Kate L. Turabian's A MANUAL FOR WRITERS (available at WPI Bookstore)
J. T. O'Connor's IQP Guidelines (available in the Project Center)
M. Gennert's Project Guidelines (available in the Project Center)

Please note that WPI does not keep copies of final reports for more than five years, or any copies of proposals. Students are responsible for preserving this material for their future professional needs.
Figure 3.
Sample Title Page
(Advisor of
Record Initials)

Project Number: 51-SBS-8880

(Division #) (4 Digit or
Alpha ID
Sequence)

COMPUTERS AND EDUCATION
An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science
by

Paul M. Jones
Jane W. White
John R. Smith

Date: May 20, 1993

Approved:
Professor Susan B. Anthony,
Major Advisor
Professor Robert C. Benchley,
Co-Advisor
BUDGET SUMMARY REQUEST FORM*

BUDGET REQUEST for (project named below)

Title:
1. Type of Project (circle)  HQP  IQP
2. Department (NQP) or Division (IQP)

3. Faculty Advisors' Initials

4. Project Registration Number
5. STUDENTS  BOX  MAJOR  YEAR  TERM AND UNITS

6. Total Cost of Project (supply details on separate sheet)

7. Total Amount of Support Request

8. Total Amount of Support from all other Sources
   (see instructions)

9. Will any funds in addition to the above be required
   later in the project?
   Yes  No


11. I have reviewed the project proposal and budget detail
    which are attached to this Budget Request for approval.

   Project Advisor's Signature

Submit to Interdisciplinary and Global Studies Division
Office
CHAPTER 6

LITERATURE REVIEW

Susan Vernon Gerstenfeld

Introduction

What is a literature review? It is literally that: a "re" view or "look again" at what has already been written about the topic. It is not a literary review, which usually is a review of a literary work such as a play, novel, book of poems or a review that has some artistic merit.

There are a variety of purposes of a literature review. The first and most obvious one is to provide background for the problem the students are attacking or put the problem into historical perspective and, at times, show how others handled similar problems in the past.

Students should ask themselves what are the different schools of thought that exist, what has happened over time, what exists that they had no idea existed that is related to the topic?

Sometimes, the literature discussed will be related to the subject but will not necessarily be in the exact form that directly addresses the topic. It may, nevertheless, help suggest alternative ways to approach the topic and reveal previously unknown sources of data. Finding that sort of information will help students determine and evaluate their own budding methodology and enable them to get an idea of theoretical bases, if any, underlying the problem they are addressing. In addition to an historical perspective, literature reviews often contain different points of view of a variety of experts. Sometimes there is consensus, but usually there is no single point of view. Controversies raised by the works of different researchers will add richness to the review and will provide the basis for a discussion of those controversies. Therefore, the reviewer is looking for the full array of perspectives. Make certain opposing points of view are not eliminated in the discussion as some people are tempted to do when a view is counter to their own beliefs.

It is important to remember that the objective is to synthesize the material through a discussion of all of the sides of an issue. Then the project's essential research question can be stated - either as an hypothesis or as a field to be described.
An important first step is to identify the major researchers or organizations that deal with the topic. Ultimately research will continue until material overlaps and until the reviewers are sure that they know the recurring themes and can recognize the work or perspectives of the major authors in the field. However, students must be careful that they do not adopt the biases or values of other authors. Whenever an author makes a definitive statement, one should look for the supporting data. The fact that authors are often sure of their own opinion or conclusions does not guarantee that they have discovered "truth." It's easy to fall in love with a particular view, especially if it confirms one's own values and opinions. Use intellectual skepticism. Always ask, "Where is the evidence?" or "Who says?"

For many projects, there are published, relevant case studies that can illustrate the complexity of the problem or elucidate alternate solutions. Reviewing them helps the students become more sophisticated in their own ability to use analytic thinking to define their project.

What Are The Potential Sources?

Undoubtedly, it will be necessary to use a variety of sources for information.

The most obvious are books and journals, but there are some loose rules about their uses. Books are very helpful for finding historical material. However, reviewers should always ask themselves if the material in the book is outdated. Is the situation different now, or possibly is it different? For example, to discuss the history of forest preservation, one might want to use both older and newer sources in order to contrast and discuss the perspectives of people in the 1920's versus people later, but to discuss procedures for carbon dating, newer sources must be used in order to be sure of having up to date information on the latest scientific advances. A danger in using books too heavily is that books often contain the considered opinion of researchers but not necessarily hard data to back up considered opinions. Books are, however, a good source of theories.

Journals are particularly helpful for many projects because articles found in them normally pass through a review process and are targeted for an academic audience that is looking for refereed information. Journals are an excellent source for studies pertaining to IQP topics. It is in them that students will find the variety of perspectives and conclusions based on analysis of data. They should use
journals to answer the questions, "What's the evidence?" or "Who says?" As mentioned before, they should not discount views they don't like. Such views are essential to putting the story together.

Papers delivered at conferences and published as conference proceedings can be used in literature reviews. Usually, but not always, those papers have passed through a review process that attests to their academic merit. Use their conclusions with caution.

Trade magazines are not the same as journals; the former usually contain material prepared to explain about a new technology or process, but they are not targeted necessarily for an audience of academics. Students should check with their advisor to see if trade magazines are acceptable in their literature review. Newspapers can be a source of unsubstantiated information. One should be careful in using them.

Written material collected from companies or organizations sometimes are appropriate for use in literature reviews. Such information includes annual statement or internally produced materials.

During the PQP phase of a project, some advisors allow students to use the information obtained through interviews as cited background material; interview material gained during the data gathering phase of the project itself will always be treated as data.

How to Find Resources?

It used to be that the first thing one did in a library was to go to the card catalog to see what books were relevant. Now we use computer searches for browsing through collections.

In addition, we use the Internet, but there are special problems associated with its use that we have to consider. We cannot assume that everything that is on the Internet reflects truth. Unless the Internet is simply used to order refereed material, there is no guarantee of the veracity of what is offered. Moreover, there is no guarantee that information that is at a particular site currently will be there in the future and be accessible to a reader checking our references. Therefore, material taken from Internet sources should be used with extreme caution.

Indices can be very useful. Many are found in hard copy in libraries and are organized by discipline: social science index, business periodicals index, etc. Many of these indices use the library of congress subject headings for generating search vocabulary.
One should not forget that libraries also contain, bibliographies, guides to microfiche and microfilms in print as well as much of the microfiche itself. In the library, users will find almanacs; annual reports, annotated guides, transactions' proceedings, directories and a host of other reference materials such as data bases, government publications, international publications and their indices.

Ask the reference librarian for help.

Students should consider that it is virtually inevitable that they will have to use consortium libraries for getting access to some of the materials for the literature review and some of them will have to go out of Worcester for information. Various libraries not to be forgotten, in addition to WPI's and those of the consortium are- the Worcester Public Library, the Worcester Law Library, Boston University Library, the library at Boston College, and MIT's libraries, to name only a few.

Locate the proper section or sections in the library and browse. It is amazing what can be uncovered by systematically browsing through the stacks of current and past issues of journals. Browsing in the stacks will never be eliminated completely by computer searches, which are, nevertheless, extremely important. Develop a sense of topic by the title of the journal, then by the title of the articles. Next scan the section heads, then read for diverse points of view.

Now That The Project Team Has Found Material, What Do They Do With It?

Critical to conducting a worthwhile literature review is an openness about material. Ask how the material obtained is related to the topic. Students should be willing to collect material that is not immediately relevant but has potential, and they must be willing to eliminate material that they first thought would be helpful but has not proven to be so.

A problem for most researchers is keeping citations within the body of the review accurate during revisions. It is very helpful to make copies of pertinent articles along with the cover page of the journal from which that article was taken. Record the volume number, an often forgotten detail, if it is not on the cover page. Later, when developing the bibliography, the project team will be grateful to have an organized and readily available source for all of the information they need. Hand copying the information often leads to abbreviating, which leads to errors later because abbreviations can often be taken to mean two different things.
When the students are ready to start writing their review, they will be faced with a set of questions:

The first question is, "What realms of knowledge do we need to know in order to reasonably develop our research questions." The literature review is the students opportunity to educate themselves and their advisor in addition to outside readers regarding the background for developing or for supporting their choice of a research question. Some of what is first put into the review may end up as an appendix later.

The second is, "Who are our readers?" Answering this question will tell the students much about the structure and style they should use for the literature review. The report will be housed in Gordon Library' Therefore, readers may not be familiar with the topic. A most helpful first section of one or two paragraphs should be a guide to the literature review. Tell the reader what material the review will be covering and why. Then, dividing the material into logical sections, the headings of which can serve as an outline for what is to come, will help the lay reader to capture the logic of the presentation. If the review will contain many technical terms, it should include a section at the back called "Glossary of Technical Terms."

Citations should appear embedded in the text, whenever one can ask "Who says?" or "What's the evidence?"

Writing is hard work. Expect to do many revisions of each section. It is important to constantly ask how the point being made is related to the discussion and to the overall presentation of material. One should not regurgitate other authors' opinions or conclusions as fact but refer to their material with qualifiers such as, "As one expert points out." or "Earlier studies indicate. " and "One perspective is...," for example. Reviewers should be critical without indicating their own opinion, which is not relevant in a review of literature. Certainly, it is appropriate to talk about what is left out of the arguments or discussions, however.

The reviewer should constantly ask, "How is this point related to the discussion of the problem?" If it is not relevant, leave it should be left out. Remember, more will be read than will be discussed. The project will need a "references" section at the back which is alphabetized. The references must be completely in order and in standard form.

After completely finishing with the writing and the multiple revisions that are necessary, revise again.
PART IV

CONDUCTING THE PROJECT

This section of the handbook presents advice to students and faculty on carrying the project to a successful conclusion after the initial proposal and literature review stages are completed. Chapter 7, the first in this section, discusses the problems that are involved in building and maintaining successful project teams whose members cooperate effectively. Chapter 8 discusses student and advisor meetings, the preparation and submission of drafts, grading procedures, and the structure of the final report. It also contains a glossary of grammatical errors and a typical schedule for a one term project.
CHAPTER 7

TEAM DYNAMICS: A MANUAL FOR PROJECT TEAM BUILDING

James Groccia, John T. O’Connor, and Susan Vernon Gerstenfeld

PREFACE

The development of a team follows a series of predictable stages. How well the team negotiates those stages will affect the outcome of the project. Projects in which students learn to work together effectively by recognizing different styles and abilities, and maximizing their interactions, are likely to be much better learning experiences than projects where partners fail to address problems with team interactions.

This chapter attempts to provide useful advice to students and faculty concerning common issues that arise in trying to solve problems together, and how those issues can be addressed. In doing a WPI Qualifying Project (IQP or MQP), what the students learn about working together may well be as valuable as what they learn about the topic. Since most professional work is done not by isolated individuals but by teams bringing together people with different skills, areas of expertise, and working styles. Such professionals know that cooperation is crucial, and that problems which interfere with successful dynamics MUST BE ADDRESSED BECAUSE THEY CAN BE FATAL TO THE PROJECT. They also know that abundant opportunities exist for dysfunctional teams to get help, and that the first step is identifying the problem.

This chapter is intended to help students and advisors begin that process of honest problem identification, from which solutions can be developed.

STAGES OF GROUP-DEVELOPMENT

As team members work together, the group generally progresses through several stages of development. One model refers to these stages as forming, storming, norming, and performing (Scholtes, 1988). [Scholtes, Peter R., The Team Handbook: How to Use Teams to Improve, 1988.] Each stage is characterized by "typical" emotions and behaviors, which are briefly described below:

Forming is a stage of transition from being an individual to a member of a group. In this stage of development, team members are typically excited about the project, but also anxious about understanding the tasks that must be accomplished and making progress. Group meetings likely center around defining the problem, how it should be attacked, and what information should be gathered. The team may spend time discussing abstract concepts or issues that do not appear relevant, or complaining about the difficulty or lack of clarity of the task. It is not unusual at this stage for group members to show impatience during
meetings, or to feel that the group is making little progress. Team members are also learning about each others' working styles, and start to develop methods of handling group conflict.

Storming, the next stage, is often characterized by tension and arguments among team members as they start to appreciate the difficulty of the project and the need to reconcile their individual style with the habits of other group members. Individuals may resist suggestions of others in the team, even when it appears that their ideas are similar. An individual may feel very positively about the project one day but very negatively the next. While this is a difficult stage and team members again may feel that little progress is being made solving the problem, the group is making important progress in defining habits and learning to work together.

In the Norming stage, the team develops a sense of cohesion, establishing and maintaining ground rules about when they will meet, how they will work as a group, and what they will work on individually. At this stage, group members have worked out many of their differences, and try to promote harmony rather than conflict. Personal friendships may develop, and group members should feel more comfortable discussing group dynamics and expressing constructive criticism. The team should now feel like they are making good progress on the project.

Finally, in the Performing stage, the group is working together effectively, making decisions, implementing them, and solving problems. Individual team members feel satisfied with the group's progress, and understand their strengths and weaknesses and those of their partners. Arguments still arise, but the team has the ability to work through them and avoid stalemate. Both students and faculty feel like a lot of work is getting done.

As the group successfully moves through the stages of group development, they essentially develop:

* trust
* the ability to manage conflict and anxiety, and
* habits and practices essential to getting the work done.

Successful teams still experience highs and lows, and periods where they make more or less progress; however, concerns about the project or relationships with other team members should not dominate the project experience. The responsibility for the group's success lies primarily with the members of the group members themselves. However, if the group has difficulty in this regard, they should not delay in getting help. Good communication among project members about their feelings concerning the process is as important as good communication about the project. For projects that take place within a seven-week term, getting help early can mean the difference between a very bad experience and an excellent one.

When a team is not functioning well, the members or the faculty
advisor will often have some clues. The following sections are
detailed descriptions of those clues or symptoms. Following each
set of symptoms is a description of what the underlying problem
might be and potential solutions.

Symptoms may have many sources, and it is up to the team and
advisors to discuss the meaning of symptoms in the context of the
particular team.

GUIDE TO SYMPTOMS, SOURCES AND REMEDIATION

SYMPTOM:

Project is ambiguous, or little progress is made.

POSSIBLE UNDERLYING PROBLEMS:

1. If the project is sponsored, students may not have contacted
   liaison.

2. Students and faculty have not negotiated a schedule of
   activities to which they adhere.

3. Students have not conducted a thorough literature review and
   thus do not know what questions to ask. Students fail to
   build effectively on previous findings.

4. The team is not functioning well as a group (see the other
   symptoms described here as well).

POSSIBLE SOLUTIONS:

1. Students should contact the liaison at the sponsoring agency,
   after which they should provide the advisor with a written
   summary of the contact and a two to three sentence written
   statement of the project goal as they understand it as a
   result of the discussion with the liaison. The goal
   statement should be followed by a list of specific
   objectives. This exercise encourages team discussion, and
   may need to be repeated several times. Each effort should
   focus the project goal further.

2. Members may be required to complete regular (for instance,
   weekly) progress reports, which may be factored into the
   final grade. Some advisors use "contracts" with students
   that are used to clarify tasks and deadlines.

3. Students should provide the advisor with a completed
   literature review. Collaboration on the literature review
will encourage group discussion of the goals of the project.

4. Students should develop a schedule of when they will meet, working steadily rather than trying to cram group activities into the last few hours before a meeting with the faculty advisor. This is particularly important when the group is trying to define the problem and project goal, which requires creativity and careful thought.

SYMPTOM:

Members make decisions independently, or one or more work alone.

POSSIBLE UNDERLYING PROBLEMS:

1. Students have not negotiated early stages of team development, including the growth of basic trust.

2. Although heterogeneous groupings are more effective than homogeneous groups and should be mixed if possible by sex, major, and group communication style, it is unlikely that everyone in the group will know what the potential impact of such mixing might be. Moreover, even good friends have different styles of working and are unaware of the impact of those differences.

POSSIBLE SOLUTIONS:

1. The process of team functioning must be clear; stages of team growth should be discussed with team members before work begins.

2. Teams need to assess their differences in working styles, using one of the diagnostic tools available to help with the diagnosis.

3. Careful attention to team building will help. Before work on the project begins, time must be spent on discussing team goals, roles, and tasks. Group members should explicitly discuss their expectations and personal individual and group responsibilities and accountability. The advisor's role also should be made clear, including expectations. Some faculty find it helpful to provide students with their expectations in writing; an example is provided in the Appendix. Positive interdependence among members of the team is the goal.

SYMPTOM:

The team is communicating ineffectively.

POSSIBLE UNDERLYING PROBLEMS:

1. Communication styles vary among members. It's easy (but
often fatal to cooperation) to assume understanding on the part of the others.

2. Conflict exists but is not discussed. Sometimes students avoid exposing conflict because they do not want to be seen as tattling. They believe they should be able to resolve conflict without assistance, or they don't believe exposing conflict "is worth it."

3. One person has been split off from the other two and has become isolated from decisions.

4. One person monopolizes group sessions and is a poor listener.

5. One member is passive in group sessions but retaliates against teammates who are more verbal by not producing according to agreement.

6. Team members do not understand the tools of consensus building.

7. Team is not meeting regularly.

8. Work on the project is not shared evenly enough by all participants, due to different levels of self discipline, and/or of time, effort, or interest in the project. Resentment among the team members builds over time, and is not brought out as grading time approaches.

POSSIBLE SOLUTIONS:

1. The project advisor may need to provide some help with models of communication styles and conflict resolution.

2. Conflict management skills should be discussed before project work begins. Students often attribute failure of communication to others.

3. The value of interdependence and balanced participation should be discussed. Arrangements are made to monitor levels of participation honestly, with the understanding that different levels will be rewarded differently in grades.

4. All problems should be considered group problems and confronted directly with all team members present.

5. The team can negotiate a signal for the person who tends to monopolize discussions. Or the advisor can request that the person who does not listen can be asked to reflect back to partners what they said.

6. The team can learn to invite the passive member's comments explicitly. If the actions of a verbally passive partner appear to be hostile or not according to agreement, the team
can be taught to confront such behavior in meetings with the faculty advisor.

7. Consensus building should be taught, and team members should have an explicit way of acknowledging when consensus has been reached.

8. While scheduling can be a problem, the solution often requires an examination of more than tight or conflicting schedules. The team will often discover during such an examination that unexpressed conflict exists. When scheduling is truly a problem, weekly advance planning will usually eliminate the problem.

SYMPTOM:

The team does not respond to advice from the faculty

POSSIBLE UNDERLYING PROBLEMS:

1. There is poor team communication among team members, or lack of understanding of goals and objectives and group dynamics.

2. One person is controlling the level of motivation of the group, or the whole group is not committed to the project.

3. The team is angry at the advisor but is not articulating its distress.

4. The team does not understand how to use new information and fails to articulate that as a problem.

5. The students have not mastered the art of information retrieval.

6. The students think that because they are closer to the problem than the faculty members, that the perspective and experience of the faculty advisor has little to offer.

POSSIBLE SOLUTIONS:

1. See earlier suggestions on group dynamics and goal setting in section on (Symptom: Ambiguous Problem). Contracts and weekly project reports may help productivity or give clues to trouble spots.

2. Advisor can invite discussion about the advising process to identify sources of tension between advisor and team. Students should be encouraged to ask for clarification and further explanation if they don't understand a point. They should also understand that disagreeing and not following faculty advice is acceptable as long as they can support that
decision with another alternative or argument.

3. Advisor can confront team regarding suspected problems such as possible intimidation by one partner of the others.

4. Advisor can explore with students their methods of finding new information and guide them to new strategies and tools.

5. Students should ask questions if something is unclear during a meeting or they have difficulty implementing the idea.

6. Advisor can communicate comments in writing and if team responds to these written comments, can discuss why written communication was more effective than verbal communication.

SYMPTOM:

Uneven team performance

POSSIBLE UNDERLYING PROBLEMS

1. The team is not considering the stages of group development, and the need to assign itself tasks so they can move together from stage to stage.

2. Project goes into "overtime" without the team members admitting it is because they cannot work things out well.

3. When fewer than the whole team approaches the advisor to complain about a partner, there may be several reasons: the motivation of one or more partner may be slacking off or has not developed, one is overly compulsive and does not have team skills, or two are closing out the third for a variety of reasons.

4. When no one from the team seeks out help between scheduled meetings with faculty, it may mean that the team is having trouble getting started or does not take the work seriously.

5. One partner may be intimidating the others; the result may be that the group level of productivity is sometimes lower than an individual partner may wish.

6. Sometimes students do not understand criticism but do not ask for clarification. One member of the group may not understand but it is rare that the whole group is not listening or understanding; however the group may not be communicating in between meetings with faculty. Students, also, can find it difficult to accept criticism, particularly from their peers.
POSSIBLE SOLUTIONS:

1. Sometimes the use of weekly project activity reports will reveal to team members how uneven their performance as a team is, which can stimulate discussions about remediation.

2. The advisor should explore with the team the potential reasons for uneven performance. If students are unable to identify reasons, advisors may want to be explicit about what they view. Often the group will need more than one session in which the discussion takes place, because they will need time to incorporate what may feel like a threat at first.

3. A letter sent by faculty to the team members at the end of each term can serve to alert the team to the advisor's assessment of both accomplishments and weaknesses and can emphasize problem areas, such as deadlines missed. In addition, these letters can help both faculty and students to close the gap between expectations and the reality of the grade earned by the team for the project.

4. When intimidation by one or more team members is a problem but is subtle, and group members are not aware of the dynamic until the advisor raises it as an issue, there may be a lag between recognition and attempts to rectify the situation. Individual team members may wish to approach the faculty to discuss this problem further, but, ideally, group members will realign control of the group process once they understand the dynamic. If that does not happen rather quickly, the advisor may want to take further measures.

5. It helps sometimes to have the students refocus on the project by rereading their project proposal or goal statement and list of specific objectives.

6. During weekly meetings, some advisors ask teams to develop a written statement of the goals and activities to be performed in the following week. The statement should contain specific assignments of individuals and should contain sufficient detail to measure progress to goals.

7. Set aside some time at the weekly meeting to talk openly and honestly about how the process of working together is going.

8. As a last resort, advisors may wish to help the team restructure tasks so that motivated students are not penalized by the work of an unmotivated partner or partners. Separate grades are sometimes used. (See Undergraduate Catalog under PROJECTS, "Group Qualifying Project Efforts.") Some advisors ask for confidential reports about the team process and achievement in the form of a letter to the advisor at the end of the project. Also, advisors should ask that students develop an authorship page at the beginning of a project report that lists individual contributions.
9. Students and faculty can discuss giving and receiving constructive criticism.

SYMPTOM:

The sections of the report clearly reflect the different writing skills of individual students and a lack of integration of sections

1. POSSIBLE UNDERLYING PROBLEMS:

2. Team members do not know how to edit an other's work.

3. Team members are not taking the time to edit each other's work.

4. The team is not allowing enough time for group editing.

5. The team is having problems that are interfering in their working together.

6. The team does not realize that in the professional world, everything goes through multiple drafts, with all team members contributing. In the real world, no professional project is finished when the first draft is finished.

POSSIBLE SOLUTIONS:

1. Since the final report is not to appear as if it had several different authors and was spliced together, the advisor and team should discuss procedures for writing the report. The expectations should be clear in advance. All authors are to follow a common format, use data consistently, and read and comment on each other's drafts before they are submitted.

2. Some advisors ask students to initial their own sections and, likewise, to signify that they have read their partners' sections.

3. The writing center can be used by individual writers to bring the quality of their work to such a level that review by partners will not create an undue burden. Some advisors suggest the use of the WPI Writing Center (Project Center top floor); others may require it.

4. The project group should establish its own interim draft deadlines consistent with the ultimate final-draft deadlines established by the advisor. Setting their own deadlines should result in an increased commitment within the project group.
5. Many advisors require each draft to be accompanied by the previous draft or drafts. This procedure tends to benefit both students and faculty because it allows both to monitor progress toward goals more easily. Also, it prevents miscommunication about expectations.

6. Some advisors will suggest that students who are having great difficulty writing read their sections aloud, first to themselves and then to their partners when the drafted section is being made ready for the advisor to read. Many conceptual and grammatical mistakes can be caught early through the use of this tool.

7. Some advisors refer to specific sections in a standard-grammar and style book when they correct drafts. This method of correction requires that students also use the same book, but it also means that students become very aware of their consistent errors, for which they have access to well described methods of remediation. In addition to the use of grammar and style books some advisors have developed their own help documents for writing, which they distribute to teams, of common errors students often make.

PLACES TO GET HELP

Students wanting support on resolving issues of team dynamics should consult with their advisor, or with the Counseling and Student Development Center on West-Street.

IF NOTHING WORKS: Most faculty prefer giving a grade for the whole team, not to individuals. But WPI faculty policy also requires an "authorship page" in which all students agree upon a listing of who did what in the final report. This authorship page can indicate equal or unequal contributions of project members, and can be grounds for assigning different grades to the team members.
APPENDIX: Example of Faculty Project Guidelines

IQP Expectations and Schedule

Your IQP should be a valuable educational experience which integrates material you have learned in classes as well as allowing you to explore new topics. Your faculty advisors and company liaisons will guide you but you should take responsibility for your own project. In one word, this means that you should take INITIATIVE!!! Come to project meetings prepared, with an idea of what you think should be done next, or with specific questions or problems if you are encountering difficulties.

The benefits you gain from the IQP experience will be proportional to the effort that you invest. Make sure the project you select is interesting to you. Also understand that you and your teammates may have somewhat different expectations regarding the effort you plan to expend, and the ways you will work together. You should discuss your expectations at the beginning of the project.

Weekly Report

You should spend 15 hours per week per person working on your project. We will meet weekly to discuss your progress and plans. You should submit a brief weekly report, preferably the day before the meeting, with the following sections:

1. Progress Report - what you accomplished during the preceding week.
2. Weekly Plan - what you plan to do in the coming week.
3. Problems/Obstacles - any concerns you might have that you want to discuss at the meeting.

The weekly report gives us an agenda for each meeting, ensuring we discuss important issues, and also helps me monitor your progress. You are encouraged to submit the report via E-mail.

I am also happy to speak with you at any time outside of the weekly meetings.

Project Schedule
During the first term, you will work to develop a clearer understanding of the sponsoring company's environment, the problem you will be addressing, and the activities you will carry out to complete the project. You should develop a better understanding of the scope of the project, and the range of solutions or techniques that are feasible. By the end of the first term, you will complete a project proposal. The attached handout details what the project proposal should contain. The proposal will be distributed to your liaisons at the sponsoring company for feedback, and to ensure that everyone agrees on the scope of your project. At the end of the first term or the beginning of the second, you will also present the proposal to the sponsoring company.

During the second term, you will do the work you outlined in the proposal. You should try to complete the work that you promised the sponsoring company.

During the third term, you will complete the final report. You should allow time for both the client and faculty advisor to provide feedback before you write the final draft. The project will be completed with a formal presentation to the client. A separate presentation to WPI faculty and students on April 21 is also required.

You can expect me, except during conferences or exam week, to read and respond to anything that you give me within 3 days. Sometimes I can provide faster turnaround time, but that depends on my schedule. If you want feedback quickly, it helps to tell me that you will be handing something in several days in advance, so that I can make a note on my calendar. Feel free to ask questions if my comments are not clear.

Grading

I will give you a letter grade evaluating your performance each term. This grade is from the final project grade, and is not likely to be changed at the end of the project (although I have this option). I will also try to give you specific feedback on your performance around midterm.

Grading criteria are difficult to articulate, but A, B, and C projects can be characterized as follows:
An A project in one in which students identify clear objectives, and then follow through to meet their objectives. The students take the initiative to identify what must be done to meet their goals. Finally, they write a good clear project report describing their efforts.

A B project is one in which students accomplish their objectives, but they rely heavily on their faculty advisor(s) for guidance. In other words, they do everything they are told to do and do it well.

A C project is one which the sponsoring company claims is satisfactory, but the quality of the work is less than the faculty advisor anticipated.

The grading criteria emphasize initiative as well as work quality because both will be important to your success after graduation.
CHAPTER 8
PROJECT CONTROL AND EVALUATION

From "IQP Guidelines" By John T. O'Connor

Preface
This chapter is based largely on a set of IQP guidelines prepared by Professor John T. O'Connor several years ago. It also contains Professor Michael Gennert's, Gennert's Project Guidelines in Appendix B. Both sets of guidelines should be viewed as examples that faculty may want to follow in establishing project control and evaluation procedures to assist their advisees. However, it is worth noting that there is a great deal of commonality between not only the O'Connor and Gennert guidelines but with those developed by a number of other faculty who have shared their personal guidelines with their colleagues.

REPORTING AND REVIEW REQUIREMENTS

IA. REPORTING AND REVIEW REQUIREMENTS: Proper guidance and direction, communication, off-campus interaction and overall project visibility are some of the ingredients of a successful IQP experience. Accordingly, to provide for these students are frequently expected to meet the following reporting and review requirements.

-Weekly Meetings and Progress Reports: A one-page weekly "Project Conference Report" (PCR) is to be sent to each project advisor on a specified day of the week, prior to the weekly meeting. The PCR should state: what was accomplished during the week; what is planned for the next week; any problem areas encountered during the week; any changes from proposed plans. These Project Conference Reports are the bases for the project meetings between the project students and their advisor(s).

-Interim Project Review: The project advisor(s) may require that a status report be submitted as a basis for an oral presentation and discussion sometime during the execution of the project.

-Chapter Drafts: All work handed in must be double-spaced, paginated, and clearly labeled as to where it fits into the report (chapter number and title, section titles, etc.). Chapter outlines (including all major divisions, subdivisions, etc.) should be approved by the advisor(s) before the chapters are written, and the outline must be

*The material in some sections is also drawn from VADEMECUM: A Manual for WPI Students in Venice by Fabio Carrera
submitted with the draft. All submissions must be grammatically correct, easily readable, and proofread (be sure to use a SPELL program with the word processor). Students should not expect the project advisor(s) to do proofreading, correcting of grammar, or try to figure out what they are trying to say. Care on their part will solve most of such problems; the Writing Resource Center may be of help to those with serious difficulties. Each submission should be read by ALL of the authors of the report. All work submitted must be dated and have the author(s) clearly indicated. Project advisors may choose to use a code sheet similar to that given in Appendix D (*Common Problems in Report Writing") for ease in making specific observations on submissions.

Fine-tuning, types of corrections may not made in the first draft. The focus is on suggestions for major directional changes, content additions, reorganizations, etc. When a new draft is submitted, all previous drafts must accompany it.

-Deadlines for Project Report Drafts: In order to minimize last minute rushes which lead to tension, confusion, and poor quality work, it is necessary that adequate planning occur for the 'last" term on the IQP. In order to complete the project on time, it will be necessary to have a complete, typed, "final' draft to the project advisor(s) by the middle (15th day of a 28 day class schedule) of that Term. That much leeway will be necessary for the advisor(s) to read this draft carefully, suggest final revisions, and for the students to make those revisions and have the final version typed and back to him (them) for final reading. The 'final' draft will incorporate all the suggestions/corrections which have been made previously by the advisor(s) on the original draft (all previous drafts must be submitted with each new draft). Since--in most cases--the 'final' draft submission will be the first time the advisor(s) has (have) seen the report as a complete unit, students should expect that the advisor(s) will have additional comments and/or suggestions.

-It is necessary that this 'final' draft be typed and complete (including Table of Contents, Abstracts, Footnotes, Bibliography, Appendices, etc.- see Section IV) so that it can be read as a total unit. Typing format should be in final form (check K.L. Turabian's style manual--latest edition). Also, since accidents do happen, copy(ies) of this typed version should be submitted rather than the original.

Final Project Report Submission: At the completion of the project, at least one clear copy of the final report must be submitted to the project advisor(s). This will be forwarded to the Registrar's Office, along with the appropriate "Completion of Degree Requirement" forms, by the advisor(s).
-Oral Presentations of Final Report: The project advisor(s) may require an oral presentation of the final project. This is particularly advisable where outside sponsors are involved.

PROJECT GRADING

B. PROJECT GRADING: The project advisor(s) will inform students as to his/her (their) grading policy during the execution of the project. There are six grading alternatives while the project is being executed: A, B, C, NR and NAC (Not Acceptable) and SP (Satisfactory Progress). Students will be graded individually; that is, students in the same project may receive different grades.

LOANS TO STUDENTS

C. LOANS TO STUDENTS: All material loaned by the advisor(s) must be returned before the advisor(s) submit Completion of Degree Requirement forms to the Registrar's Office.

REPORT FORMAT

No single format can be appropriate for all IQP project reports. The following information summarizes important elements of the contents of an IQP report. Students and their advisors are encouraged to revise this format when appropriate. In particular, the titles of Chapters IV and V may be more well-suited to some IQP topics than to others.

As indicated above, WPI has adopted Kate L. Turabian's A- Manual for Writers (latest edition), from the University of Chicago Press, as its style manual. This is available in the bookstore and should be consulted frequently while the report is being written.

TITLE PAGE

A. TITLE PAGE: The Title Page should include the title of the project, the name(s) of the author(s), the date of final approval (month and year), and the name(s) of the project advisor(s). Careful thought should be given to selection of and appropriate project title, and it must include no more than fifty characters.

ABSTRACT

B. ABSTRACT: The WPI transcript Abstract should present a concise overview of the entire project, and must not exceed eighty words (WPI rule). However, the project advisor(s) may prefer to include a longer Abstract (or Executive Summary) in the project report itself.

The transcript Abstract should clearly state the project
objectives, rationale, provide a brief summary of the procedure employed, and describe the final results produced from the project. The Abstract should be written as a completely self-contained section; (i.e., it should provide sufficient information to a reader who may read no other portion of the project).

Arnold (1) describes an Abstract as follows:

The Abstract is not only the most important section of the report or paper, but also the most difficult to write. Effective abstracts:

1) must contain enough specific information to satisfy the needs of a research worker looking for sources of information and of an administrator looking for a progress or status definition;

2) must be a complete self-sufficient unit;

3) must be made as short as possible without violating accuracy or eliminating essential information;

4) must be written in fluent, easily understood language;

5) but be consistent in tone and emphasis with the parent report or paper; and

6) should make the widest possible use of numerals and standard, generally recognized abbreviations.

Abstracts and Executive Summaries are generally written after the remainder of the project is complete, and has been reviewed. As such, they all too often suffer from being hurriedly done. They are the sections of the reports which are usually read first and a reader will often go no further if they do not arouse his or her interest. Thus, careful thought and planning is important to insure that these sections reflect the quality of the entire report.

AUTHORSHIP PAGE

C. AUTHORSHIP PAGE: The Authorship Page should state clearly--for each project student--the responsibilities assumed separately, as well as those assumed by the group (or a subgroup). References should be made to particular sections of the project report.

TABLE OF CONTENTS

D. TABLE OF CONTENTS: A Table of Contents is useful for directing readers to the location of specific information they seek; it also allows them to obtain a quick overview of the contents of the entire project. All titles and subtitles in the Table of Contents must be exactly the same as in the text, and
all divisions/subdivisions used in the text must be present in the Table of Contents. The typing format for each level of division must be consistent from chapter to chapter. (See Turabian manual for correct typing format.)

TABLE OF TABLES
E. TABLE OF TABLES (see above)

TABLE OF FIGURES
F. TABLE OF FIGURES (see "TABLE OF CONTENTS" above)

CHAPTER I--INTRODUCTION
G. CHAPTER I--INTRODUCTION: This chapter introduces the subject of the project to the reader. It should include broad project objectives and explain why the project is worth doing.

The Introduction should address the following questions:

What is the project subject?

What are the goals of the project? The sub goals?

Why is the project being conducted? (What is the project's specific purpose?)

What makes this project a suitable IOP? (What are the major societal and technological dimensions of the project, and how are they to be addressed?)

Who is the project audience? Who will utilize the project results? (The project audience should be viewed more broadly than merely the faculty.)

How will the results be utilized?
In what physical form will the project results be presented?
What is the general procedure which will be employed in conducting the project?

The final paragraph/paragraphs of this chapter should briefly preview the contents of each of the succeeding chapters. It is important that this section present an accurate description of what appears later in the report; any last minute adjustments must be reflected in this section.

CHAPTER II--BACKGROUND
H. CHAPTER II--BACKGROUND (or LITERATURE REVIEW): The function of this chapter is to give the intelligent, but non-specialist, reader all the introductory information needed to understand the project. This chapter gives the setting of the project. It elaborates upon, documents, details, etc., many of the topics touched upon in the Introduction (Chapter I) in a more cursory fashion (e.g., the importance of the project, debates concerning
aspects of the project, specifics on alternatives, benefits to be derived from the results of the project, etc.). It must also supply the reader with any technical background which is necessary to understand the project and fully explain possible alternatives being evaluated in the project. This chapter is based on a thorough literature review.

The opening paragraphs of every chapter should discuss the major divisions of the chapter in such a way as to make the flow of the chapter clear and logical. Of course, the divisions mentioned in this paragraph (or paragraphs) should match the divisions which the reader notes when he/she skims the chapter for content and structure before reading it. Often major divisions are—in turn—subdivided further in the text. In this case an introductory sentence/paragraph following such major division should describe the division's structure, content, progression, etc.

This chapter is usually quite lengthy and extensively documented ('footnotes' may be placed all together at the end of the chapter to facilitate typing). Full citations are necessary for all quoted material, all specific facts which are not general knowledge, and all quantitative data.

As noted above, this chapter is based on a thorough literature review—particularly in relationship to the alternatives being considered. Certain elements should be present in the review of any article, book, or other source:

-Bibliographic Information: Author and title are usually mentioned in narrative: journal (or book), volumes, number, date, pages (or publisher, place of publication—in the case of books), are mentioned in footnoted. (See Turabian for correct format.)

-Thesis or Conclusion: Main statement, conclusion, judgment, or hypothesis put forward in this source.

-Argument: Major arguments put forward in support of thesis or conclusion. The thesis/conclusion may be supported by empirical work or by inductive/deductive reasoning. In the case of empirical work, the specifics of the work should be presented very clearly (e.g., sampling procedure, sample size, assumptions made, study protocol, statistical significance of conclusions, etc.).

-Critique: In some situations it may be appropriate to critique the article, book, etc. Are there logical errors in the arguments presented? Are the assumptions made sufficiently realistic (these are often worth questioning)? Obvious errors—or problems in relating this source to your project should be noted.

CHAPTER III--PROCEDURE
I. CHAPTER III--PROCEDURE: Starting from the goals of the IQP this chapter describes how the goals were achieved. The function
of this chapter is to tell the reader specifically *how* the project was conducted. How did the students do their research for the project? What indexes, which libraries, what correspondence did they utilize? What surveys did they conduct? What interviews did they hold? What experiments did they perform? What methods of analysis were employed? In general, what research procedures did they follow and, why? This chapter is often divided into two areas: resources used and project method.

Frequently projects evaluate alternative programs to achieve a desired end (e.g., to suggest changes in a particular social policy). If so, what criteria were used to evaluate the alternatives? What specific measures were utilized in order to gain insight into these criteria? (A matrix, detailing the criteria and measures on one dimension and the alternatives considered on the other, may be a valuable table to include in this chapter).

This chapter is at the heart of the project. It should convince the reader that the author clearly understood the problem and has (have) pursued a logical task-sequence to achieve the project's objectives.

Project execution should be described in a clearly defined sequence of tasks. Major tasks should be broken into sub tasks. These may be tabulated, or represented graphically by Task Charts or PERT Charts.

CHAPTER IV--RESULTS

J. CHAPTER IV--RESULTS: In this chapter the raw results of the project including some of the most original and unique parts are presented--the specific data, information, findings, designs, etc., as they relate to the particular project. The structure of the chapter should be very similar to that of methodology, since this is the actual outcome of the procedures outlined there. The key is to keep the Results separated from the Analysis (unless one purposely decides to unify the two), by avoiding major manipulation of the data and by presenting the data as is.

Often this chapter presents the specific information which enables a choice to be made between enumerated alternatives. That is, the data on the specific criteria and measures used in the evaluation--as described in Chapter III--are presented in this chapter for each of the alternatives evaluated.

Frequently the main organization of this chapter is according to the alternatives considered, and--within each alternative--by criteria and measures. In this way the reader is presented with the full complement of information for each alternative. Although the information is given in this chapter, comparisons among the alternatives are usually not made until Chapter V. Missing items of information must be noted explicitly; otherwise, the reader does not know whether they were inadvertent omitted.
CHAPTER V--ANALYSIS OF RESULTS

K. CHAPTER V--ANALYSIS OF RESULTS: This is the most cerebral of all chapters, as it requires some serious thought to analyze the results of the project. Often, the analysis involves the comparison between data obtained in one location, applicable to problem at hand, and data obtained elsewhere. Other times, the analysis may try to explain why a certain observed behavior came about. In the case of a feasibility study, the analysis would weigh pros and cons, leaving the conclusions to the Conclusions chapter. There is no unique way to describe the analysis chapter; each project is different.

Often in this chapter, comparisons among alternatives are made. In this case, the main organization of this chapter may be by criterion, and within the heading--by specific measures. For example, "cost" and "effectiveness" would be two criteria for comparing different technologies in health care, and "direct labor costs" and "health status changes" could be among the measures used. This chapter sets the stage for the conclusions drawn in the final chapter.

CHAPTER VI--CONCLUSIONS AND RECOMMENDATIONS

L. CHAPTER VI--CONCLUSIONS AND RECOMMENDATIONS: The conclusions chapter combines the analysis with the goals to draw some conclusions about the project matter. In a feasibility study the conclusions would pertain to the feasibility or unfeasibility of something or other. In quantitative studies, the conclusions would bring forth hypotheses regarding specific behaviors or phenomena. The conclusions would be subdivided into groups if the methodology had identified major areas to be studied.

In this chapter the overall decisions are made and documented, based on the results and analysis thereof of the two proceeding chapters. This chapter is much more likely to be read than the entire report, and it must be written with great care. Assumptions, value judgments, data and procedural limitations, etc., must all be stated very explicitly. one should not assume that the reader has digested all previous sections of the report; some repetition cannot be avoided.

It is also most important to qualify conclusions appropriately, and not make statements which cannot be substantiated by the project procedures and data. Students should know--and state clearly--the limitations of their analyses. The implications of their findings should also be noted, and followed by suggestions for action and for future research.

A summary table (or tables) can be a particularly valuable device in this chapter. Data or conclusions represented previously in different formats can be highlighted here to support the project's conclusions. Such a table (or tables) can also serve
to call the reader's attention to places where important data are missing and to the limitations which such omissions place on the project's conclusions. (Such a table may take the form of an annotated matrix, such as that described above under Chapter III.)

Recommendations are a logical sequence to the conclusions. They suggest remedial actions to some problem or further in-depth studies in some specific areas.

**BIBLIOGRAPHY**

M. BIBLIOGRAPHY: (See Turabian for correct typing and organization).

**GLOSSARY**

N. GLOSSARY: Where the technical vocabulary necessary to understand the project would not normally be understood by the non-specialist reader, it is often necessary to add a Glossary section. When the technical vocabulary is first used in the text, it is usually appropriate to define it briefly and also refer the reader to the Glossary where a more complete explanation is given.

**APPENDICES**

O. APPENDICES: Appendices are reserved for important material which is too voluminous for inclusion within the project text and would thus disrupt the smooth flow of information. All material placed in an Appendix must be referenced within the text of the project. Where necessary, separate Appendices should be used—rather than one large Appendix—to facilitate easy reference to the materials. Each Appendix should be lettered (i.e., A, B, C... ), given an appropriate title, paged, and included—with appropriate title and page—in the Table of Contents.

**FOOTNOTE**

APPENDIX:

COMMON PROBLEMS IN REPORT WRITING
(Instructions to Advises)

A. GRAMMAR/SPELLING/PUNCTUATION

1. MISSPELLED word.

2. A sentence should not end with a PREPOSITION.

3. Incorrect in NUMBER. Should be singular (or Plural).

4. Do not switch TENSES of verbs.

5. Incorrect PUNCTUATION.

6. Not a COMPLETE sentence.

7. Use a dictionary to HYPHENATE words.

8. Avoid RUN-ON SENTENCES.

9. Work should be PROOFREAD before being submitted.

10. Avoid SPLIT INFINITIVES.

11. VERBS must agree with subjects in person and number.

12. Check on the correct use of COLONS and SEMI-COLONs.

13. "DATA" is a plural word, so it takes plural modifiers and plural verbs.

14. Use PERSONAL PRONOUN (not impersonal pronoun) here.

15. PRONOUNS must agree with antecedents in person and number.

16. This should be an ADVERB, not an adjective.

B. FORMAT (Arrangements of Parts, Typing, Form, Etc.)

1. Except for portions of the 'Introductions' Chapter, the report should (generally) not be written in the FIRST PERSON.
2. Table of Contents, Table of Tables, Table of Figures and Charts are to be understandable without reference to the text accompanying them. Therefore, UNEXPLAINED ABBREVIATIONS are not to be used and sources are to be cited in full.

3. FOREIGN PHRASES ARE (usually) underlined or italicized in the text.


5. SLANG and COLLOQUIALISMS do not (generally) belong in a formal report.

6. INCORRECT citation.

7. INCOMPLETE citation.

8. DIVISIONS/SUBDIVISIONS are not correct. Check Turabian.

9. Make sure TITLES and SUBTITLES of each chapter are exactly the same in "Table of Contents* as in the text.

10. Refer reader to appropriate APPENDIX.

11. Would not this material be more appropriately placed in an APPENDIX?

12. Be consistent re CAPITALIZATION.

13. The first time an ABBREVIATION is used it should be placed in parentheses, preceded by the spelled out version; e.g., *The Interactive Qualifying Project (IQP) is... 1

14. ALL TITLES and SUBTITLES in the report need to be self-explanatory so that readers skimming the report can correctly assess its contents.

15. None but the most common of ABBREVIATIONS should be used in report titles and subtitles (see #14 above).

16. FOOTNOTES may be placed at the end of the chapters as wend Notes* (for easier typing).

17. ABSTRACT has to be less than eighty (80) words (WPI rule).
18. No citations in ABSTRACT.

19. All sources used in ENDNOTES (or FOOTNOTES) should be listed in the BIBLIOGRAPHY.

C. CONTENT (Research Report Procedures, Style, Clarity, etc.)

1. Full citations are necessary for all QUOTED MATERIAL, all specific facts which are not general knowledge, and all quantitative data.

2. Use PARALLEL construction.

3. Personal BIASES, SARCASM, ETC, should not be evident in a formal report.

4. Avoid VALUE-LADEN words and expressions; attempt a MORE OBJECTIVE presentation.

5. Do not draw conclusions which do not follow from your data/analysis. ALL SPECULATIONS should be clearly identified as such.

6. Make sure all your ASSUMPTIONS are clearly stated.

7. Meaning is UNCLEAR/AMBIGUOUS. Rework.

8. For the sake of clarity, keep MODIFYING CLAUSES/WORDS close to the word(s) they modify.


10. POOR/AWKWARD English.

11. Words are (apparently) MISSING.

12. LOGIC is unclear.

13. A bit more VARIETY in wording would be welcomed by the reader.

14. ORGANIZATION is a problem for you. Please hand in a brief paragraph by paragraph outline with your submissions.
15. Avoid CATEGORICAL, UNQUALIFIED STATEMENTS which are either not documented or not attributed to experts in this area.

16. Usually it is necessary to quote only when the particular wording is essential. Otherwise, PARAPHRASE appropriately for the point you are making, and cite source.

17. You're BEGGING-THE-QUESTION; explain more fully.

18. INAPPROPRIATE WORDING for a formal report.

19. Please discuss only ONE IDEA PER PARAGRAPH.

20. This is too WORDY.
APPENDIX B

Gennert's Project Guidelines

PROJECT GUIDELINES apply to all projects: Sufficiency, IQP, PQP, MQP, Independent Study, Directed Research, Research Assistantships, Thesis, although certain items may not be applicable to all projects. A successful project includes the following ingredients:

Getting Started

- Relevant coursework should be taken before the project is started. Isn't that the whole idea of The WPI Plan?
- A well-written proposal will be due at the beginning of project work. This may be part of an earlier PQP if appropriate. The proposal must explain what the problem is and why it is important, and sketch a method of attack. The proposal does not need to be comprehensive, but it should let a reader know that you understand the problem.
- · Read "How to Write a Project Proposal," available at the Project Center. You must follow the instructions in HtWaPP in order to receive funding.
- · A schedule, covering the entire project, must be developed at the beginning of the project. The schedule should include milestones and deadlines.
- · The topic must be well-researched. The library is an invaluable resource; all project students should be familiar with it. If you do not know how to perform a literature search, the library staff will help.
- · Attend relevant seminars and colloquia on campus and nearby. This is one of the best ways to learn what others are doing.
- · A project should represent a significant effort. The average amount of work will be 15--20 hours per week. Sponsored Research Assistants should spend 25--30 hours per week on the project.

Meetings and Reports

- · Project review meetings will be held every week. If you will be unable to attend a scheduled meeting, call or email ahead of time.
- · Written progress reports will be submitted at, or better yet, emailed prior to, the weekly meeting, with a summary at the end of every term or semester. The weekly progress report can be short --- 1 or 2 pages --- but must state what has been accomplished since the last report, what is expected to be accomplished in the next interval, and what obstacles were encountered. One progress report per project. The end of
term/semester summary, project proposal, or final report may be substituted for the weekly progress report.

- You are strongly encouraged to submit condensed versions of high-quality reports and theses to conferences and journals. All thesis students must submit at least one paper based on the thesis.
- Final Report

- A well-written final report or thesis is required. Correct spelling and grammar are mandatory. Contact the Writing Center if writing assistance is needed.
- A complete draft must be submitted at least 10 days before the final deadline. Expect revisions. Submitting sections earlier is encouraged. Thesis readers must be given at least 10 days to review submitted materials. If the project advisor is to review a draft before the reader, submit the draft at least 20 days before the deadline.
- You must prepare copies of final reports for all interested parties, including advisor, thesis reader, off-campus advisor or sponsor, and registrar.
- All submitted work must be original.
- There are occasions when direct quotations are unavoidable. Indicate exactly which material is a direct quotation, and provide a reference including page numbers.
- Minimize direct quotations; quote only the material needed to support the point.
- Always quote the original source; never quote one author quoting another.
- Rules of attribution apply equally to drafts and finished work. Do not let anyone suspect plagiarism.

Presentation

- A well-organized final presentation is required for IQP, MQP and thesis projects. This may be satisfied by an on-site presentation for off-campus work, or CS Colloquium, CS MQP presentation, Research Group meeting, or other forum.
- Use professional tools for your presentation, e.g., PowerPoint, Presentation Manager, Light Pro and browser.
- Expect to go through a dry run of the presentation with the project advisor.

Software

- All software must be of professional quality.
- It must be thoroughly documented, including a User's Manual, if appropriate.
• It must be thoroughly demonstrated. Warning: Normally well-behaved demos have been known to break in the presence of a project advisor!
• It must be thoroughly debugged. If written in C, it must pass through lint.
• It must be portable. Use makefiles or imakefiles. If your project advisor cannot compile and run it, it isn't good enough.

The Web

• You are expected to find and post information on the World-Wide Web.
• Maintain a current homepage, with a link to Your project.
• Let your advisor know where you and your project's web pages may be located.

Responsibilities

• You are responsible for finding out exactly what administrative paperwork is required and for preparing same. This includes Completion of Degree Requirements (CDR) forms, Thesis forms, etc.
• All project students share responsibility for the project's success. All team members should understand the entire project, and should read all weekly progress reports, term/semester summaries, proposal, and final report.

Grading

• All project students will usually receive the same grade, although exceptions can be made.
• No passing grades will be awarded until all borrowed materials have been returned.
• Grading policy: "A" indicates exceptional work, not just good effort. Significant original ideas, effort that goes far beyond what is expected, and meticulous implementation all contribute to an "A.lt" "B" indicates good work, while "C" is for acceptable performance. "SP" indicates satisfactory performance at "A," "B," or "C" level. An "NR" grade will be given when little or no work has been performed during the grading period or when awarding additional credit is inappropriate. The final grade for a multiple-term/semester project may, at the advisor's discretion, supersede intermediate grades. "NAC" indicates unacceptable work.
PART V

COMMON IQP METHODOLOGIES
CHAPTER 9

INTRODUCTION AND GLOSSARY OF IQP RESEARCH METHODS

The remainder of this handbook contains introductions to several of the most important research methods commonly utilized in conducting IQPs. Part V examines two qualitative methods that have been very popular in the past: surveying and interviewing. In Part VI the focus is on quantitative methods. While they have been far less popular, techniques such as cost/benefit and investment analysis, life-cycle costing, regression analysis, statistical hypothesis testing, and even modeling have found regular application in IQP work.

Not all important research methods are covered in the chapters below. To provide at least some information on those that are not this chapter concludes with a glossary of one paragraph definitions of most of the common IQP methodologies that have been identified in past reviews. The list currently includes the following: survey research, participant or natural observation, interviewing, focus group, case study, content analysis, historical analysis, risk analysis, statistical analysis (regression, hypothesis testing, etc.) cost/benefit analysis, life cycle costing.

IQP Research Methods:

Survey research
Survey research refers to a body of techniques for collecting data on human characteristics, attitudes, thoughts, and behavior by obtaining responses from individuals to a set of prepared questions. The goal of virtually all surveys is to enable the researcher to predict accurately the characteristics or thoughts of a predefined group of people.

Natural and participant observation
Natural and participant observation are two approaches to conducting field research which is "defined as 'the study of people acting in the natural courses of their daily lives. The field worker ventures into the worlds of others in order to learn firsthand about how they lived, how they talk and behave, and what captivates and distresses them.' Field research is carried out in natural settings and is frequently viewed as a way of empathizing with and understanding the subjective meanings of the people being studied. " In participant observation the investigator tries "to attain some kind of membership and or close attachment to the group that he or she wishes to study. In doing so the participant observer attempts to adopt the perspectives of the people in the situation being observed. The participant observer's role is that of "conscious and systematic sharing, insofar as circumstances permit, in the life activities, and on occasion, in the interests and effects of a group of
Interviewing

Interviewing involves "a face-to-face interpersonal role situation in which an interviewer asks respondents questions designed to elicit answers pertinent to a research hypotheses" and records their answers. "The questions, their wording, and their sequence define the structure of the interview." Interviewers must learn established techniques for ensuring that the interview data are unbiased, and determine who to interview, how many people to interview, what type of interview to conduct, and how the interview data will be analyzed. (Nachmias, p232)

Focus groups

Focus groups are a variation of in-depth qualitative interviews in which several people are interviewed together in a flexible and exploratory group discussion format. In focus groups the emphasis is on interactions between participants rather than between the researcher and participants, and researcher adopts a role that is more like a moderator that a questioner. The purpose of focus groups is to explore people's ideas in a public setting so that the interviewer can observe how they react to each other's ideas, when they challenge each others views, and how their opinions are formed. Focus groups are most appropriately used when it is important to obtain opinions after they have gone through a public process in which they are shared with and commented on by peers.

case study

The case study is an in-depth analysis of one particular organization or event. It allows for a thorough examination of a particular situation, but the results of such a study cannot be generalized beyond the single case. One authority has characterized the case study as follows: "A case study is an empirical inquiry that investigates a contemporary phenomenon, within its real-life context especially when the boundaries between phenomenon and the context [in which the phenomena occurs] are not clearly evident." "The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from prior development of theoretical propositions to guide data collection and analysis." (Yin, p13)

Content analysis

Content analysis is a technique for drawing inferences from existing records or documents (ranging from the Congressional Record to personal ads in a newspaper) in a systematic and unbiased way. Its advantages include an ability to study large populations and document naturally occurring trends overtime; however, it is subject to biases of interpretation and the researcher cannot control the collection of data.
Historical analysis in IQPs

Historical analysis in IQPs: Historical analysis involves critical assessment of both change and continuity over a period of time. It requires an effort to understand the past in a larger context that goes beyond simply seeing it from the perspective of the present. Historical analysis in an IQP usually investigates the extent to which a technology interacts with evolving aspects of the culture of its time, as that interaction is revealed through the rigorous examination and assessment of sources either from the time period (called primary sources) or from later periods consisting of secondary sources written by other historians about the issue. The sources are various—artifacts, manuscripts, books, newspapers, diaries, letters, art works, census records, tax lists, in fact, any and all human records that remain for the historian to access. The focus may extend from the most personal to the most generic/statistical, depending on how the questions concerning the investigation are framed. Methods of historical analysis stress inductive reasoning from evidence to inference and range widely in form from those that quite closely approximate social science methodologies and may involve quantitative analysis to those which eschew such approaches in favor of the theoretical, literary, and philosophical. These different approaches reflect the two broad positions taken by historians in assessing the role of complex causal forces in history: On the one hand, that humans, even when acting technologically, are never entirely free to make history as they see fit, but must act within the context of historically developed social and cultural forces that follow to some degree general laws of human behavior. Or, on the other hand, that the record of human action, driven by human decisions and unforeseen consequences, can only be understood within the reconstruction of the narrative of historical events that alone give meaning to those actions. Both views of history, however, require consideration of a range of alternative explanations and perspectives, recognizing that understanding is advanced not through simple assertion but by engaging in a critical dialogue with what other people have said about an issue.

Risk analysis

Risk analysis consists of a body of techniques for evaluating decisions made under conditions of risk and uncertainty. The latter are decisions in which the payoff or benefit to the decision maker from a given course of action depends on the state of the world (what will happen in the future) which is uncertain. In determining their optimal choice decision makers must frequently take into account the probabilities associated with the different possible states of the world.

Regression and correlation analysis

Regression and correlation analysis are used to study relationships among variables. Regression analysis is a technique for estimating the causal relationship between a
dependent variable and one or more independent variables from actual data when the relationship among the variables is statistical in nature rather than exact. Correlation is a method for examining the relationship between two variables considered symmetrically in the sense that neither is assumed necessarily to dependent directly on the other.

**Hypothesis testing**

**Hypothesis testing** is used to confirm that a statistical relationship or result has not arisen purely by chance. For example, the statistical hypothesis tests that are performed as part of a regression or correlation analysis determine the probability that a relationship estimated by regression or uncovered through correlation analysis did not arise purely by chance.

**Cost/benefit analysis**

**Cost/benefit analysis** is a method used to assess the social desirability of undertaking a project. Costs and benefits, some of which may be inherently non-pecuniary in nature, must be measured on a common monetary scale and compared. As a project's costs and benefits ordinarily occur at different times their comparison typically involves appraising an investment decision.

**Investment decision analysis**

**Investment decision analysis** consists of a body of techniques for evaluating decisions that involve a sacrifice now in return for future benefits, when both the sacrifice and the benefits can be measured in monetary units. They involve alternative ways of taking into account and evaluating the time value of money. Some examples include net present value, net future value, profitability index, internal and modified internal rate of return and annual worth.

**Life cycle costing**

**Life cycle costing** involves determining the total cost of alternative methods of accomplishing a given end over the entire time horizon affected by the decision. Costs occurring in different times are evaluated on common scale by taking account of the time value money using techniques similar to those employed to analyze investment decisions e.g. present value, annualized cost, etc.

**References**


CHAPTER 10

INTRODUCTION TO SURVEY METHODOLOGY AND DESIGN

Prepared for the
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by

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Assistant Professor
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1. Introduction

Research projects like the IQP that examine the interface between science and technology and society often require the collection and analysis of social data. The most common response from beginning researchers to this need for data is to conduct a survey. After all, everyone has had experience answering surveys, and it is usually a simple and straightforward procedure. Many people conclude from this experience that writing and administering their own survey will be a simple and straightforward matter as well.

However, in actuality, the intuitions people form about survey research from their own experience are often incorrect. To test your own intuitions, you might consider how you would answer the following true/false questions (answers appear at the end of the chapter just ahead of the References):

T  F  1. Determining the opinions of the population of a city of 10,000,000 people requires a much larger sample than an opinion survey of a city of 100,000 people.

T  F  2. Randomly choosing names from a telephone directory is the best way to choose a sample for a telephone survey.

T  F  3. Survey questions should appear in random order.

T  F  4. Posting a survey on a web site is a good way to reach large numbers of people and to increase sample size.

T  F  5. If too few people from the first survey sample chosen fail to respond, a second sample should be chosen to increase the number of respondents.
An understanding of the answers to these and many other questions is essential for conducting scientific surveys that yield accurate, unbiased, and generalizable results. Yet it is a rare person indeed who can explain the reasoning behind such questions correctly without having made an effort to study survey design and methodology. In fact, there really is little reason to expect success in survey research without formal study of the topic. Basic social science research methods are often more complicated, more difficult to learn, and more counterintuitive compared with basic methods in other sciences since the subjects of study, human beings, are more complicated. Atoms and chemicals, for example, don't try to figure out the goals of your research, don't have a bad day, and don't change their minds from one moment to the next!

Social scientists, by conducting countless studies and experiments over the past several decades, now have a good understanding of how to conduct a survey. From such obviously important questions as how to select a random sample to seemingly trivial details such as whether it is better to include a preprinted business reply envelope or a stamped envelope for people to use to return mail surveys, the answers are available in the published academic literature and in textbooks. There are even excellent books on the subject written especially for beginning researchers [see, e.g., Rosnow and Rosenthal (1996) and Salant and Dillman (1994)].

Thus it is now possible for students who have never conducted a survey before to learn about and implement the basic principles of scientific survey design and methodology as part of their IQP. The goal of the present work is to introduce you to these basic principles and to describe where you can go to learn more.

II. Alternative Social Science Methodologies

Surveys can be a powerful and useful tool for collecting data on human characteristics, attitudes, thoughts, and behavior. And, sometimes, conducting a survey is the only available option for acquiring the data necessary to answer an important research question. However, doing a survey is not the best approach for every project. Before committing to do a survey, for example, you should first consider whether or not your project team has or can obtain the appropriate background. Achieving a background in psychology, sociology, or another social science through WPI's Social Science Requirement is important for understanding what researchers have already learned about the behavior of human individuals, groups, and societies and how this knowledge was acquired. In addition, a familiarity with the basic principles and methods of statistical analysis is essential for analyzing survey data.
Conducting a thorough literature review of prior research on your topic is also an important prerequisite for conducting a survey. There are literally thousands of survey professionals and social scientists conducting and publicizing the results of surveys and studies on every conceivable topic. It is possible that your research questions have already been asked and answered by other researchers. Although students are often disappointed when this happens, it also opens up new opportunities: by learning from the experience of other researchers, your own project will improve in quality; and, after reading and analyzing prior research in your area of interest, you will be able to choose a more specific topic that is unique and important.

Survey studies also have several inherent limitations, including the following:

1. A single survey can establish whether or not a relationship exists between two variables but is not sufficient to determine the direction of causality. For example, a survey on the topic of aggression might find a significant correlation between the number of times children argue or fight and how much time they spend playing video games. However, this would not constitute sufficient evidence to demonstrate that playing video games causes aggression, because the following explanation is also consistent with the data: children who are more aggressive to begin with are more likely to spend time playing video games.

2. Survey studies rely on "self-report" data, that is, they depend on participants to truthfully and accurately report on their attitudes and characteristics. This does not always happen. For example, some respondents may deliberately answer questions incorrectly or flippantly. However, if the survey is conducted in a professional manner, this occurs less often than you might think. A much greater concern is that subjects may simply commit "honest" errors of omission, confusion, or false memory.

3. Survey studies are subject to well-known types of bias. For example, since respondents know they are being studied, and have at least some idea why, they may change their answers, either consciously or unconsciously, to show themselves in a better light or to conform to the expectations of those who are studying them. It is also possible for experimenters to deliberately or inadvertently write survey questions that bias people to respond the way they want them to.

4. If conducted properly, surveys can accurately represent the opinions and judgments of a population of people. However, this doesn't mean that these opinions are correct. Although survey data can be used to inform decision making and public policy, they cannot substitute for expert judgment and analysis.

5. Finally, conducting a scientific survey is not a trivial undertaking. Scientific surveys require careful research and
planning, are labor intensive, and can take weeks to implement and analyze. If your project team has less than a full 7-week term to devote to the survey portion of your IQP, you would probably be well-advised to try to answer your research questions using another method.

These limitations of survey studies do not mean you should not conduct a survey: all social science methodologies have their own unique set of limitations. However, before deciding on conducting a survey it is important to investigate available alternative methods and weigh their pros and cons in relation to the goals of your project. The following are some of the major alternatives to conducting survey research:

1. **Naturalistic observation** involves the systematic watching and recording of naturally occurring behavior. Since the subjects do not even know they are being studied, the researcher can be confident that the behaviors are natural but does not have much control over what happens. See Martin and Bateson (1986).

2. **Content analysis** is a technique for drawing inferences from existing records or documents (ranging from the Congressional Record to personal ads in the newspaper) in a systematic and unbiased way. Its advantages include an ability to study large populations and document naturally occurring trends over time; however, it is subject to biases of interpretation and the researcher cannot control the collection of data. See Weber (1985).

3. **Formal experiments** on human subjects follow the scientific method, randomly assigning subjects to alternate experimental conditions that are identical except for a single hypothesized causal variable. They allow the direction of causal relationships to be identified, but often achieve this by sacrificing "external validity," that is, applicability to real-life situations. See Chapter 4 of Judd et al. (1991) and Chapters 7 and 8 of Rosnow and Rosenthal (1996).

4. A **case study** is an in-depth analysis of one particular organization, such as a university, a business, or a community. Although a case study allows for the thorough examination of a particular situation, the results of such a study cannot be generalized beyond the single case. See Yin (1989).

5. **Secondary data analysis** is the reanalysis of existing survey data that were collected by someone else for a different purpose. Its major advantage is the enormous savings in time and effort gained by avoiding the collection of new data; its primary disadvantage is the lack of control over what information was collected and how it was collected. See Chapter 13 of Frankfort-Nachmias and Nachmias (1996).
6. In participant observation researchers become involved in the daily lives of their subjects and record detailed field notes of their observations and experiences. This allows the researcher to engage in an open-ended exploration that allows great flexibility; however, the observations are difficult to generalize to other situations and people and the researcher's presence can alter people's behavior. See Emerson (1983).

7. Personal interviews or focus groups involve the face-to-face questioning of people selected for their particular knowledge, interests, or availability rather than at random. Although they allow for a more exploratory approach, the results cannot be generalized beyond the individuals or groups. See Survey Research Center (1983) and Morgan (1988).

For a review of alternative social science methodologies, see Frankfort-Nachmias and Nachmias (1996) and McKenna (1995).

III. Sampling

The goal of virtually all surveys is to enable the researcher to predict accurately the characteristics or thoughts of a predefined group of people. Toward this end, it sometimes makes sense to attempt to survey the entire population of interest (for example, when this population is small, such as a company with fewer than 100 employees, or when it is important for reasons of fairness to allow every individual the opportunity to respond, as is the case with student course evaluations). However, in the great majority of cases, surveying the entire population is impractical and unnecessary. If chosen wisely, a relatively small sample or subset of a population can yield highly accurate predictions, so limited resources are best spent not by trying to survey everyone but by pursuing other goals such as obtaining a high response rate (see Section IV). Professional polling organizations, for example, are now consistently able to predict how more than 100 million people will vote in national elections with a margin of error of just a few percentage points by surveying fewer than 2000 individuals! They are able to do this by employing complicated sampling techniques that ensure that their survey participants are highly representative of the U. S. voting population as a whole.

For most survey projects, however, the basic technique known as simple random sampling is sufficient. The goal of simple random sampling is to, insofar as possible, ensure that every member of a chosen population has an equal chance of being included in the sample. In order to choose a sample, a list of people from which a sample can be drawn (called a sampling frame) must be found or constructed. ¹ All such lists must be carefully

¹ It is certainly possible to conduct a scientific survey without constructing a sampling frame in advance. For example, students can be approached to answer a survey in a common area such as
evaluated to ensure that they are correct and complete. Some sources of lists are notoriously problematic: telephone directories, for example, do not contain people who do not have phones or people who have unlisted numbers, and do contain multiple listings of the same people and people who have relocated since the directory was published. And, even apparently excellent lists can contain errors or omissions. For example, a set of class lists obtained from the Registrar's Office can be a good source of names for a survey of WPI students, but they are not flawless: such lists, for example, contain undergraduates from other schools and high school students who are taking WPI classes and don't contain the names of WPI students who are away at Project Centers. Once a satisfactory list is obtained, the sample should be chosen randomly. This can be accomplished in a variety of ways, for example, by consulting a random number table in a statistics textbook, by using a computer program that generates random numbers, by selecting every nth person on the list after randomly choosing a starting point, or even by drawing thoroughly mixed names out of a hat.

No matter how they are drawn, all samples can be expected to misrepresent the population to some degree. Although such "sampling error" cannot be avoided, it can be reduced by obtaining a sample of sufficient size. Beginning researchers often seek a simple rule of thumb for determining sample size. However, no such rule exists: the question of how large a sample to draw depends on how a researcher answers the following two questions:

(a) How much sampling error is acceptable?

(b) How much variation is there in the population on answers to the most important survey question?

The answer to question (a) partly depends on the available resources: every increase in sample size will increase accuracy, but will also increase the amount of time and money necessary to complete the project. This trade-off between accuracy and cost is unavoidable. The answer also depends on the consequences associated with making an error. For some projects it is sufficient to estimate a population characteristic within 10 or 15%; in other situations, when the costs associated with making an error are higher, estimates within 5% or less may be desired.

The answer to question (b) can only be estimated (if the population variance were known precisely there would be no need
to conduct a survey!). This estimate might come from a literature review of similar studies or from the results of a survey pretest (see Section VIII).

Once these questions are resolved, the necessary sample size n can be calculated from the following formula:

\[ n = \frac{(SD)^2}{(SE)^2}, \]

where SD is the estimated standard deviation (the square root of the mean squared error) of the variable in the population and SE is the size of the acceptable standard error (the standard deviation of the set of all possible sample means). Thus, for example, suppose that the most important variable for a given survey project is SAT score, and that a literature review uncovers that the standard deviation of SAT scores nationally is 150. Suppose further that the researchers would like to be 95% confident that they will be able to estimate the average SAT score of their target population within plus or minus 30 points. The phrase "95% confident" means that the sample mean will fall within a range of 2 standard errors 95% of the time, implying a standard error of 15. The required sample size would then be

\[ n = \frac{(150)^2}{(15)^2} = \frac{22,500}{225} = 100 \]

It should be noted that the results of this equation yield the number of completed, usable surveys that must be obtained. This number will typically be only a fraction of the surveys that are administered. To calculate the number of surveys that must be administered, divide n by the expected response rate of the survey (see Section IV). It should also be noted that in most survey projects, it is desirable to obtain reliable estimates for important subgroups of the target population. In such cases, the above formula should be used to calculate the required size of the subgroups, which can then be added together to obtain the overall required sample size. For example, in the SAT example, if the same level of reliability were required for subgroups of freshmen, sophomores, juniors, and seniors, the overall required sample size would be 400 instead of 100.

In certain cases a simple random sample is insufficient. For example, imagine a project designed to compare the SAT scores of men and women at WPI. A simple random sample of 200 students would yield about 160 men and 40 women -- too few women to draw conclusions about with a high degree of confidence. In cases such as this when an important subgroup of a population is comparatively rare, it must be oversampled, that is, selected at a much higher rate than it occurs in the population. Thus, if comparing men and women is an important goal, it makes more sense to draw a sample containing 100 women and 100 men. Overall population estimates could still be obtained by weighting the

\[ n' = \frac{n}{1 - \frac{n}{N}}, \] where N is the population size.

\[ ^2 \] For small populations, the following correction to the formula should be made:
results obtained from each group according to its true prevalence in the population; in the present example, the mean SAT score for men would be multiplied by .8 and that for women by .2 before adding them together.

For further information on sampling see Chapter 5 of Salant and Dillman (1994); Henry (1990); and Chapter 8 of Frankfort-Nachmias and Nachmias (1996).

IV. Response Rates

Selecting an unbiased sample of sufficient size is an important component of any scientific survey, but is not enough to ensure that the people who answer are representative of the larger population from which they were drawn. It is also important to obtain a high response rate. The response rate of a survey is simply the number of completed, usable surveys obtained divided by the number of people who were asked to complete a survey. If this fraction is too low, there is a strong possibility of "nonresponse error," that is, that estimates are biased because those who didn't respond to the survey have different characteristics or opinions than those who did respond.

To illustrate the potential biasing effect of a low response rate, suppose that 500 surveys are sent to randomly selected WPI students asking which of two alternate food service plans they prefer. Suppose further that 150 students (30%) respond, and that 98 of them choose Plan A and 52 choose Plan B. Thus a clear majority of 65% are in favor of Plan A. However, this simple analysis assumes that nonrespondents have the same opinions as respondents. What if, for example, the 350 nonrespondents in fact have just a slight preference, say, 55% vs. 45%, for Plan B? The true percentage preferring Plan A in this case would in fact be just 0.3 x 65% + 0.7 x 45% = 51%, which is not significantly different from 50%. What if, instead, the 350 nonrespondents had a strong preference, say 70% vs. 30%, for Plan B? In this case the true percentage preferring Plan A would be only 0.3 x 65% + 0.7 x 30% = 40.5. Under this scenario, the results obtained from the 150 respondents completely misrepresent the preferences of the student body!

Of course, a low response rate to a survey does not guarantee that results will be biased. In the hypothetical food service survey, for example, it is entirely possible that nonrespondents had the same preferences (65% in favor of Plan A) as those who did respond. The problem is there is simply no way of knowing for sure what nonrespondents are like or how they are thinking. The only sure way of reducing this uncertainty is to obtain a high response rate in the first place. For example, suppose that the food service survey which reported that 65% of students preferred Plan A had achieved a response rate of 70% rather than 30%. Under this scenario, even if nonrespondents strongly disliked Plan A (say, 70% preferred Plan B instead),
Plan A, as suggested by the survey, would still be the preference of the student body: \(0.7 \times 65\% + 0.3 \times 30\% = 54.5\%\).

Obtaining a high response rate to a survey requires a substantial investment of time and effort. A single mailing or phone call to each potential respondent is completely inadequate and is likely to result in a response rate of 20\% or lower. This happens not because most people aren't interested or don't want to help, but simply because they are busy and have many competing demands on their time. Thus, some mail surveys never get opened because they are confused with junk mail and get thrown out; those that are opened often end up under a large stack of correspondence that people never find the time to get around to. And, telephone interviewers, if they don't get a busy signal or an answering machine, are highly likely to get a person who refuses to talk because they have company, or are eating dinner, or are on their way out the door, or have to put the kids to bed. There are two things a researcher can do to increase the chances that people will take the time to respond:

1. Design a questionnaire (and accompanying material) or telephone introduction that makes it immediately clear to people that responding to the survey is both important and easily accomplished (see Section VII).

2. Design an implementation plan that includes multiple mailings or phone calls, if necessary, directed at each potential respondent (see Section IX).  

If these established techniques are employed, response rates of 60-70\% or higher can be achieved. However, in some cases, in spite of a researcher's best efforts, the response rate turns out to be less than 60\%. In such cases the researcher should investigate and attempt to identify, insofar as possible, how similar or different nonrespondents are from respondents on relevant variables. Sometimes this can be accomplished with available information, for example, in most cases the gender and geographical location of nonrespondents is known, and occasionally sample lists contain other variables that can be compared. It is also possible to randomly select and telephone a small sample of nonrespondents and launch an all-out effort to

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3 There is an alternative to the time-consuming and costly procedures necessary to obtain a high response rate to a survey, but it has a significant drawback. This alternative involves finding a "captive audience," that is, obtaining permission for a mass administration of a survey to a group of people already gathered at a particular time and place, for example, a regularly scheduled class of students or a meeting of employees. Although this neatly resolves the response rate problem (nonattendees, however, should be counted as nonrespondents), it creates another problem: the obtained sample is not random. This strategy should therefore be used only as a last resort when the time and resources necessary to obtain a high response rate through traditional means are unavailable.
get them to answer at least a couple of brief questions that will allow them to be compared with respondents. Even people who refused to participate initially will often agree to an interview that takes just a minute or two.

For further information on response rates see Chapter 2 of Salant and Dillman (1994) and Chapter 2 of Groves (1989).

V. Choosing the Right Survey Method

There are several different ways of administering a survey. The most common methods are sending written surveys through the mail, asking survey questions over the telephone, and conducting face-to-face interviews. Each of these methods can be effective and can yield a high response rate in certain situations. However, they each have a unique set of strengths and weaknesses, and can be ineffective if applied under the wrong circumstances. The choice of method for a particular project should therefore be made only after careful consideration of the following factors:

1. Available resources. Mail surveys require money to make copies and to buy stamps and envelopes but their implementation does not require much labor. Telephone surveys require a substantial time commitment from several people to conduct interviews but fewer monetary resources are needed (unless long distance charges are accrued). Face-to-face surveys require even more labor due to the travel time involved but again require little money unless large distances must be covered. Thus, the choice of which method to use often comes down to the relative availability of money and labor. When labor costs are high (e.g., when interviewers must be paid), mail surveys are sure to be the cheapest alternative. However, when money is tight and free labor is available, telephone or face-to-face surveys may be a better choice. Chapter 4 of Salant and Dillman (1994) contains

4 The growing popularity of the internet and WWW has recently made it possible to conduct electronic mail surveys. However, the majority of the population still does not use email, and those who don't differ in several important ways from those who do. Email surveys should therefore only be used when it is not necessary to generalize results beyond the population of email users or when the specific population of interest (e.g., students at a technological university) contains a very high percentage of email users. Although the empirical work necessary to identify the strengths and weaknesses of email surveys has yet to be done, it is likely that they will prove to be susceptible to many of the same problems as regular mail surveys (for example, email can be sent to the wrong address, lost, forgotten, or ignored just as easily as snail mail and it can be deleted with the click of a button!) (see Clayton et al., 1996). If so, the same principles necessary to obtain high response rates in regular mail surveys (personalized messages, compelling introductions, easy-to-answer questions, and multiple contacts) will likely also prove necessary in email surveys.
detailed budget examples that can help you determine the probable cost of each method for your particular project.

2. Time pressure to produce results. Mail and face-to-face surveys usually take a substantial amount of time, at least a month and more typically two months, to complete since each contact involves mailing or travel time. However, in a telephone survey, multiple contact attempts can easily be made in a matter of a few days. Thus, if results are needed quickly, a telephone survey may be the only viable option.

3. Sensitivity of topic. Mail surveys are filled out in the privacy of respondents' homes and they never meet the researchers. They therefore offer a high degree of "anonymity." As a result, if a survey includes sensitive topics or information which people may be reluctant to divulge, mail surveys will generally produce higher response rates and more accurate responses.

4. Complexity of survey questions. In a mail survey, respondents have the written questions in front of them, whereas in a telephone survey, questions must be heard and remembered. If a survey contains complicated questions with many different response options or technical questions that need long explanations, it can be very difficult to administer over the telephone, and a mail survey is more appropriate. For surveys that include pictures or diagrams, a telephone survey is out of the question. For surveys that include especially complex or technical questions, a face-to-face survey where respondents can ask questions while reading the survey may be needed.

5. Probability of introducing error or bias. All survey methods are susceptible to error and bias, but in different ways. For example, telephone and face-to-face surveys can be biased by inconsistencies in the behavior of different interviewers or by interviewers inadvertently giving respondents verbal or nonverbal clues about what sort of answer is appropriate or expected. Mail surveys, in which no interviewer is present, are not subject to these problems. However, they are more susceptible to certain other kinds of error. For example, nonresponse error can be more problematic for mail surveys because respondents can look over the survey before deciding whether or not to participate. This greatly increases the chance that respondents and nonrespondents differ on important variables related to the survey topic. In addition, in a mail survey, the researcher cannot control who exactly in a household is filling out the survey and cannot verify that they are doing so conscientiously and completely. In contrast, in telephone and face-to-face interviews, the interviewer can exercise greater control over the situation and catch errors and omissions as they occur. Overall, telephone and face-to-face interviews allow for the possibility of obtaining somewhat more complete and accurate results than mail surveys, but only if interviewers are well-trained and consistent.
6. Characteristics of respondents. Sometimes the appropriate survey method is determined by the type of people who are being studied. For example, if a researcher wants to survey the homeless or illegal immigrants, for whom address or phone lists are unavailable, a face-to-face survey is the only viable option.

For further information on choosing a survey method, see Chapter 2 of Dillman (1978).

VI. Question Wording

Taking the appropriate steps to minimize sampling error and nonresponse error, while necessary and important, is not sufficient to produce a scientific survey. The questionnaire itself must be written in such a way that the questions are valid (that is, the questions measure what the researcher intends them to measure), reliable (the questions would yield the same results if administered at different times or to different samples), and unbiased (the questions are written in such a way that people are willing and able to provide accurate answers). Writing good questions is perhaps the most difficult and complicated part of any survey project, yet it is also one of the most often ignored.

Beginning researchers tend to make four common mistakes when constructing a questionnaire. First, they simply don't ask enough questions. Surveys from beginning researchers tend to be just a page or two in length, containing a dozen or fewer questions. Such a short survey will rarely if ever capture the information needed to answer a research question definitively. For example, just the demographic questions necessary to describe who the respondents are (questions about gender, age, income, educational background, ethnic background, and so on) can fill a couple of pages. 5 Also, many seemingly simple research questions require multiple survey questions. For example, recall the hypothetical SAT survey from Section III. Did all of the students even take the SAT? If not, what tests did they take? Did they take it multiple times, and, if so, which score or scores should they report? Should they report their combined score or report math and verbal separately? When did they take the SAT (the scoring system was changed a few years ago)?... thus even a question as simple as "What was your SAT score?" can

5 Demographic questions serve three important functions. First, when compared with population data, they can serve as an important indicator of the existence of sampling error and/or nonresponse error. Second, since demographic variables are often important predictors of attitudes and behavior, they can help researchers interpret their results. Finally, they serve a documentary function. Over the course of time, typically several studies are done on the same or similar topics by different researchers. In order for the studies to be compared, they must all have collected the same demographic information.
require multiple survey questions to answer. In addition, in many cases it makes sense to measure the same variable in multiple ways, since a comprehensive set of questions will be subject to less measurement error than a single question. For example, a survey designed to assess pro environmental behavior might ask respondents about what, specifically, they consistently recycle, what they do, if anything, to conserve energy or water, how often they take public transportation or carpool, whether they buy and use recycled products, what environmental organizations they belong to or contribute to, what they set their thermostat to in the winter, what they did to celebrate Earth Day, and so on. Any one of the single questions could give a misleading picture of an individual; e.g., someone may have been sick on Earth Day; may have had to let their membership in Greenpeace lapse due to lack of funds; or may not have control over the thermostat in their room. However, the entire set of questions taken as a whole would yield a reasonably accurate picture of how much a person does or does not do to help the environment.

A second common mistake made by beginning researchers is to ask too many "open-ended" questions. In open-ended questions, no restrictions are placed on the type of answers that are allowable. The alternative to open-ended questions are "closed-ended" questions in which the possible responses are listed for the respondent. Thus, for example, the question "Where do you live?" is open-ended and the question "Do you live: (a) on-campus or (b) off-campus?" is closed-ended. Open-ended questions, as useful as they are in everyday life, generally make for poor survey questions because they allow a wide variety of possible answers that often stray from the original intent of the question. For example, consider the following possible answers to the question "Where do you live?: "on Park Street," "in an apartment," "in New England," "in the suburbs," "upstairs." Even when respondents do interpret an open-ended question the same way, it can be very difficult to compile and compare answers: for example, how would the following answers to the question "Do you like sushi?" be quantified and compared?: "I love it!," "Sort of," "No, it's disgusting!," "Not really," "Sometimes," "Yes." Closed-ended questions are much easier to quantify and analyze than open-ended questions and place fewer demands on respondents, and therefore they are emphasized by most scientific surveys. They do, however, have one potential drawback: in order to compose a good closed-ended question, you must be able to anticipate the great majority of the possible different answers to the question from an often diverse set of respondents. When this is not possible, open-ended questions are preferred, and most surveys will include one or a few such questions to make sure respondents have some chance to convey information not revealed by the closed-ended questions.

A third common survey error is to place too much emphasis on questions about attitudes (e.g., Do you like Bill Clinton?) at the expense of questions about behaviors (e.g., Who did you vote
for in the 1996 U. S. Presidential election?). Questions about people's personal actions will generally yield accurate answers. Attitudes, however, are much more difficult to measure because (a) people are sometimes simply not aware of their true attitudes; (b) weakly held attitudes are easily changed; (c) people tend to respond as if their attitudes are long-held and well-formed even when they were just made up on the spot; and (d) attitudes are very sensitive to minor variations in how questions are worded. In particular, attitude questions should never be used as a substitute for behavioral questions since the correlation between attitudes and behavior is often quite low. Attitude questions can play an important role in a survey -- but only if their limitations are understood and if questions about respondent's actual behavior are included as well.

A fourth common mistake made by beginning survey researchers is to fail to think carefully about how to word survey questions. Beginning researchers tend to worry exclusively about the content of questions, resulting in data that are biased by easily avoided problems with the details of question wording. There are literally dozens of issues related to the precise wording of questions that should be carefully considered when constructing a survey. Thus, all survey questions should be put through a "debugging procedure" in which several quality control questions are asked, including the following:

1. Is the question one which respondents can easily answer based on their experience?

2. Is the question simple enough, specific enough, and sufficiently well-defined that all of the respondents will interpret it in the same way?

3. Does the question contain any words or phrases which could bias respondents to answer one way over another?

4. Is it clear to respondents exactly what types of answers are appropriate?

5. Does the question focus on a single topic or does it contain multiple topics that should be broken up into multiple questions?

6. Are any listed response options mutually exclusive?

7. Are any assumptions implied by a question warranted?

This process of writing, debugging, and revising survey questions can't be done in a day or even a week. Identifying all of the flaws and weaknesses in the wording of survey questions typically takes even experienced research teams a couple of weeks or more of review, during which they create, critique, and revise a dozen or more drafts of their questionnaire. There are, however, a couple of strategies that can make this process a little easier. First, it helps considerably to review textbook examples of
poorly written survey questions and suggested fixes, such as those available in Chapter 6 of Salant and Dillman (1994) and throughout Fowler (1995). Second, it is often possible to borrow or adapt questions used and published by other researchers which have already been subjected to a careful review process. So long as the original source of the question is properly acknowledged, this practice is encouraged since it promotes replication of existing results by other researchers, a necessary part of research in any domain.

For further information on question wording, see Fowler (1995); Chapter 11 of Judd et al. (1991); Chapter 6 of Salant and Dillman (1994); and Chapter 11 of Frankfort-Nachmias and Nachmias (1996).

VII. Questionnaire Design

Constructing valid, reliable, and unbiased questions is necessary but not sufficient for creating a good questionnaire: how the questions are organized and presented also deserves careful consideration. The look and feel of a questionnaire serves as an important cue to respondents as they think about how to react to a request to answer a survey. If it is apparent within the first minute or two that the survey is important and easy to complete, people are highly likely to participate; if instead they are not given compelling reasons to take the time away from other activities to answer the survey or if the questions appear to be too difficult, a lot of people will toss the questionnaire into the trash bin or put it on the bottom of their to-do list, resulting in a low response rate. If it is apparent from examining the survey that the researchers put in a lot of time and effort to produce a professional-looking and carefully crafted document, people will likely respond with carefully considered, honest answers; if instead, the survey seems to be poorly organized or contains typographical or other careless errors, respondents will be equally as careless when answering the survey.

Thus questionnaire designers should take several steps to ensure that their instruments make a good impression on potential respondents and to encourage people to respond conscientiously, including the following:

1. Mail surveys should be accompanied by a "cover letter" that briefly introduces the study and explains why it is important and useful. The cover letter should also include three messages that are known to be important for encouraging people to respond: (a) a promise that the respondent's answers will be kept confidential; (b) a statement that describes why their responses, specifically, are necessary for the success of the study; and (c) an accurate estimate of the time it will take to complete the survey (which should generally be no more than 10-15 minutes).
2. A good survey is not a random series of questions but is organized. Questions on related topics should be grouped together into sections and placed under descriptive headings. The sections should appear in order from most to least important or most to least closely related to the central topic of the survey.

3. Questionnaires should contain more than just questions. Introductions and transitional statements that briefly explain to respondents what kind of questions they are going to get and why are important to include in a survey because people find questions much easier to answer when the organization of the survey is made apparent to them.

4. The first few questions on a survey should be carefully chosen, since they must serve to grab respondents' attention and help motivate them to continue to fill out the survey. It is best to begin with a few questions that are easy to answer and that address the most important, central issue of the survey.

5. The format and presentation of the questionnaire must be designed to make it easy to complete without error. Thus, for example, the typeface, type size, and spacing should be easily readable by most anyone (some respondents may have poor eyesight!) and the printing should be of high quality. A particularly important feature of good questionnaires is standardization, that is, when possible, different questions should be presented in the same format in order to reduce the time and effort required from the respondent.

For further information on questionnaire design, see Chapter 4 of Dillman (1978) and Chapter 7 of Salant and Dillman (1994).

VIII. Pretesting

In spite of a research team's best efforts, final drafts of surveys often contain errors, omissions, typos, questions that are confusing, biased, or poorly worded, and other problems. This is to be expected, since writing a survey is a complicated undertaking which requires the consideration of many important issues, some of which conflict with each other. And, constructing closed-ended questions requires researchers to anticipate how respondents will answer the questions -- a task which cannot be accomplished without error (if it could, there would be no need to conduct a survey!). However, there is a simple and effective step that researchers can and should take to reduce the chance of survey errors: conducting a survey pretest.

In a pretest a small, but representative sample of respondents are asked to complete the survey and are also interviewed either after each question or at the end of the survey to find out what they were thinking while answering the questions. This gives researchers an opportunity to identify any
problems people are having with a survey, such as terms or phrases they find confusing and questions they find too difficult to answer, and to verify that different respondents are interpreting the questions in the same way. Researchers can also test questions for biasedness by asking respondents to guess what the researchers are predicting or expecting the survey results to show. If substantially more respondents than would be expected by random chance can guess the researchers' hypothesis, it is highly likely that the survey contains biased or leading questions.

For more information on pretesting see Chapter 5 of Fowler (1995).

IX. Survey Implementation

Even a perfectly prepared questionnaire is of no use to a researcher if large numbers of people fail to complete it. Thus the main goal of any survey implementation plan should be to obtain a high response rate. Beginning researchers tend to assume that a single attempt to contact each respondent will result in an adequate response rate. However, this greatly underestimates the necessary level of effort: research has shown time and again that the only effective way to achieve survey response rates of 50% or higher is to make repeated, personalized attempts to contact and encourage potential respondents to participate. For a mail survey, the need for multiple mailings results in substantially higher copying and postage expenses and adds weeks of time to the research schedule. For a telephone survey, the need to make multiple calls to most respondents can double the amount of time interviewers spend on the phones. And for a face-to-face survey, the additional travel time required to make multiple visits to households or businesses can become prohibitively expensive. It is therefore critically important for survey researchers to develop a realistic implementation plan that takes these costs and delays into account.

A typical implementation plan for a mail survey would include 4 separate mailings:

1. The first mailing is an introductory postcard or letter informing people that they will be asked to participate in a survey and explaining what it is about.

2. The second mailing typically includes a cover letter, the survey, and a stamped return envelope.

3. A week or so after the survey is sent out, a third mailing is sent to all potential respondents to remind people to fill out the survey, if they haven't already done so.
4. Finally, a couple of weeks later a fourth mailing, including another copy of the survey, is sent to those people who have not yet responded to the survey.

All of these communications should be professional in appearance and should show evidence of personal attention, such as the use of authentic rather than computer-generated signatures and stamps rather than preprinted envelopes.

Telephone and face-to-face surveys should also, when possible, begin with an initial mailing that informs people that they will receive a telephone call or visit from a researcher. Again the principle of multiple attempts to contact people and encourage them to respond should be applied; a researcher should not give up on a respondent unless 3 or more phone calls or visits have been attempted, at different times on different days. It is also important to keep a careful record of the results of each contact attempt, particularly if the attempts will be made, as they often are, by different interviewers. The bulk of the preparation necessary to implement telephone and face-to-face surveys, however, involves various efforts which are necessary to make sure that different interviewers are collecting data using the same procedures. For example, a "script" should be prepared and faithfully followed by each interviewer for the first couple of minutes of an interview, when the study is described and participation is requested. It is also necessary to try to anticipate, insofar as possible, the questions respondents are likely to ask during interviews, so that each interviewer can refer to a standard set of "stock" answers.

For further information on survey implementation, including examples of mail correspondence and telephone interviewer instructions, see Chapters 5 and 7 of Dillman (1978) and Chapter 8 of Salant and Dillman (1994).

Ethical Considerations

X. Ethical Considerations

All social science researchers have an ethical obligation to protect the welfare of the people they study. Although survey studies tend to be relatively innocuous compared to some alternate methodologies, there are three ethical principles that all survey studies should follow:

1. Respondents should be informed that participation is voluntary and that they may omit answers to any particular questions if they choose. Certain steps may be taken to encourage participation (e.g., you might explain the importance of your research or how, as part of a carefully selected sample, their answers are needed to help ensure the validity of the study). However, in the final analysis, people have every right to refuse to participate and should not be coerced.
2. Adequate measures must be taken to protect the confidentiality of respondents. Although overall survey results may be presented publicly, individuals should never be publicly identified or associated with their individual responses.

3. Any promises made to the survey respondents (e.g., that you will send them a copy of the survey results when they are available) must be kept.

There are two situations in which further steps must be taken to protect the rights of survey participants:

1. If your survey includes sensitive questions about intimate relationships, personal habits, or illegal practices or any question that might induce embarrassment, anxiety, shame, psychological stress, or any other strong emotional reaction in your respondents.

2. If your survey is part of an experimental design that involves giving alternate versions of your survey to different groups of people. (This turns your survey project into a formal experiment on human subjects, for which stricter ethical guidelines apply. For example, researchers are required to document the informed consent of experimental subjects and to debrief them on the reasoning behind the experiment when it is completed.)

In either case you should receive approval from WPI's Human Subjects Research Committee before proceeding with your study.

For further information on the ethics of social science research see American Psychological Association (1982); Chapter 20 of Judd et al. (1991); and Chapter 4 of Frankfort-Nachmias and Nachmias (1996).

XI. Reporting on Survey Methodology

Gaining a thorough understanding of the principles of scientific survey design and implementing them in your study is not by itself sufficient to gain acceptance of your findings and conclusions. It is also necessary to convince the readers and users of your study that your methodology was sound. This requires the inclusion in your project report of a methodology section which explains in detail what you did and how you went

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It should be noted that protecting confidentiality doesn't mean that you, as the researcher, don't know who participated or who said what (in a mail survey, e.g., you must keep track of this information at least temporarily in order to know who needs to be sent a follow-up reminder). It simply means that you don't tell anyone else or allow them to find out.
about doing it, so that readers can judge the quality of your work for themselves. The methodology section also provides an opportunity for researchers to explain the reasoning behind the methodological choices that they made and to anticipate and answer the questions that skeptical readers are likely to ask.

For survey projects, the methodology section of the project report typically contains the following five sections:

1. **Respondents.** The first section should describe the people who participated in the study and answer such questions as: How many respondents are there? What are their general demographic characteristics (e.g., age, education, income, ethnic background)? Why did you choose to study this group of people and not other possible groups? What was done to ensure that respondents were treated in an ethical manner?

2. **Sampling Design.** The second section should describe in detail the design of the sampling plan. For example, How was the sampling frame compiled? How was the size of the sample determined? Was simple random sampling employed or was a more complicated sampling design necessary?

3. **Questionnaire Design.** The questionnaire used in the study should appear exactly as seen by or read to respondents in an appendix to the project report, and this third methodology section should guide the reader through its design and construction, answering such questions as: Why is the survey organized the way it is? Why does it include the questions it does and not alternate possible questions? What was the "debugging" procedure used to make help make choices about question wording? What was done to make the questionnaire easy to fill out? Was the survey pretested? If so, how was the pretest conducted and what did it reveal about the survey?

4. **Procedure.** The fourth section should describe each step in the implementation of the survey, and address such questions as: What survey method was employed and why? When was the survey administered? What steps were taken to increase the response rate to the survey? What response rate was obtained? What was participation in the study like, from the respondents' point of view? If interviewers were used, how were they trained and how did you ensure that different interviewers used the same procedures? Did any unexpected problems occur? If so, what were they and how were they resolved?

5. **Limitations.** As discussed in Section II, all survey studies have certain methodological limitations in common. And, most surveys have additional limitations that are imposed by constraints on time and money and by other factors unique to a particular project. Thus researchers are not expected by readers and users of their work to have conducted the "perfect" survey study. However, researchers are expected to demonstrate that
they have a thorough understanding of the limitations of their own work and that they have made reasonable judgments about how to spend their limited time and resources. The final section concerning methodology should therefore acknowledge the limitations of the study and explain how they may affect the interpretation of the results. For example: To what extent was the sampling frame representative of the population, and what are the potential impacts of any errors or omissions? To what extent was the study subject to sampling error? What was the response rate? What, if anything, is known about the nonrespondents? Which questions are more sensitive to possible errors or biases than others?

XII. Data Analysis (A Very Brief Introduction)

The primary purpose of conducting a survey, of course, is to produce data that will help answer important research questions. Once collected, the data must be collated, organized, summarized, and described. Most beginning survey researchers understand this, and faithfully go about calculating summary measures such as means, frequencies, standard deviations, and correlations and creating tables and graphs that illustrate important findings. Such activities are appropriate, necessary, and important. However, they are not sufficient to allow conclusions to be drawn from survey data.

Unless the entire population of interest was surveyed and the response rate was 100%, the data provided by surveys are estimates of population variables. This means they are almost surely wrong. The estimates may be off by just a small fraction of a percentage point or they may be off by 10 percentage points or more, but they are off by some unknown amount. The amount of error cannot in fact be determined with certainty. However, it is possible, through applying a type of statistics called "inferential statistics," to determine the likelihood of different sizes of errors and therefore how much confidence one can have in the sample estimates. This determination of the degree of confidence in the results depends on the sample size and the pattern of variation in the data, and thus cannot be done simply by examining summary measures, tables, or graphs: it requires additional statistical calculations, and it is irresponsible to report sample estimates without completing this additional step.

The logic involved in inferential statistics can be illustrated in the simple case of determining the appropriate degree of confidence in a sample mean of a single variable by returning to the SAT example described in Section III. In that section the following formula was presented for calculating the necessary sample size \( n \) for a survey project:

\[
\text{n} = \frac{(\text{SD})^2}{(\text{SE})^2}.
\]
This formula can be turned around to yield the following formula for calculating SE, the standard error of the mean:

\[ SE = \frac{SD}{\sqrt{n}} \]

where is SD is the estimated standard deviation of the variable in the population (the standard deviation of the sample serves as the estimate) and \( \sqrt{n} \) is the square root of the sample size (see also footnote 3 regarding the finite population correction). Thus, suppose in the SAT study a sample size of 100 was obtained, the mean SAT score in the sample was 500, and the standard deviation of the SAT score in the sample was 150. The standard error of the mean in this case would be

\[ SE = \frac{150}{\sqrt{100}} = 15. \]

Assuming the SAT scores are normally distributed (i.e., form a symmetrical "bell-shaped" curve about the mean score), there is a 68% chance that the population mean SAT score is within plus or minus one standard error, or within plus or minus 15 points of the sample mean of 500. Such a range of possible population values, in this case ranging from 485 to 515, is called a "confidence interval." Many different confidence intervals could be constructed depending on how much confidence is desired. In fact, a 68% confidence interval does not represent a very high degree of confidence, since the population mean will fall outside the stated interval 32% of the time. Social scientists prefer a lower chance of error, and generally use a 95% confidence interval, which corresponds to a range of plus or minus two standard errors. Thus, the results of the SAT study might be best described as follows: "We are 95% confident that the population mean SAT score falls between 470 and 530."

Statistical inference calculations of the sort presented in this simple example are an essential component of any scientifically defensible analysis of survey data. However, for most survey projects the necessary statistics quickly become much more complicated than in this simple case, and a detailed discussion of these more complicated statistical techniques is beyond the scope of the current work. Thus, in order to learn more about how to conduct an appropriate analysis of your data, you will have to consult other sources. In particular, your research team should take the following steps:

1. Develop a strong foundation in the basic logic and terminology of both descriptive and inferential statistics. This foundation may come from a formal course in statistics or from reading descriptions of data analysis written especially for beginning researchers (see Chapters 10-15 of Rosnow and Rosenthal, 1996; Chapters 15-17 of Judd et al., 1991).

2. Determine which specific statistical analysis techniques are appropriate for your data (e.g., regression, analysis of variance, chi-square analysis) and learn how to apply them and
interpret the results. This is best accomplished by consulting comprehensive introductory textbooks on statistics for the social sciences, such as Agresti (1997), McCall (1998), McGrath (1997), or Shavelson (1996).

3. Learn how to code survey data into a data matrix that can be analyzed by a computer program. Chapter 15 of Judd et al. (1991) contains a good description of this coding process.

4. Become proficient in the use of an appropriate statistical analysis software package. One of the packages available to WPI students is called SAS, and there is a SAS tutorial available on the WWW at

http://www.math.wpi.edu/Course_Materials/SAS/tutorial96.html

At this point it should be fairly obvious that data analysis is not a trivial undertaking. It is not uncommon, in fact, for a project team to take a month or even an entire 7-week term to learn about data analysis techniques, to code, analyze, and interpret their data, and to write up the results, so this time should be planned for and allocated at the beginning of the project.

XIII. Conclusion

This document has provided an introduction to the basic principles of scientific survey design and outlined the steps that all beginning survey researchers should take, including:

1. Determining if a survey study is the best way to answer your research questions.

2. Obtaining a random or representative sample of sufficient size.


4. Creating a questionnaire that is valid, reliable, and unbiased.

5. Designing a questionnaire and implementation plan that achieve a high response rate.

6. Developing procedures that ensure that people are treated ethically.

1. Conducting a scientifically defensible statistical analysis of the survey data.

Decades of research on survey design and methodology have demonstrated the importance of these basic steps. When they are followed, survey data can be a critically important source of
information that supports decision making and policy formation. When they are ignored, survey data can be inaccurate and biased, and the decisions and policies based upon them ineffective or even harmful.

Many students are surprised when they find out how complicated survey design and methodology is and how much time and effort it takes to produce a high-quality survey project. However, there is no substitute for the level of effort and attention to detail that is required to obtain high quality: social science research methods of all types are inherently complicated because people and societies are complicated. In the case of survey research, at least, the basic information is now available to undergraduate students in this document and other easily accessible and highly readable books, so high quality surveys should be achievable by the majority of IQP projects. Of course, in some cases quality must be sacrificed to some degree due to constraints on time and budget. This is understandable and such surveys are still worth doing: as long as the limitations of the project are understood and acknowledged, most surveys will yield useful information.

Finally, it should be emphasized that this document is intended to serve as an introduction to survey design and methodology and is therefore incomplete in several important ways. For example, only the simplest sampling techniques are described, many important issues related to question wording have been omitted, detailed examples of questionnaires, cover letters, and other documents have not been included since they are readily available from other sources, and data analysis is presented in a particularly abbreviated fashion. Given these limitations, it is imperative that students consult additional sources on survey design and methodology and data analysis when planning their projects. The recent books by Salant and Dillman (1994) and Rosenthal and Rosnow (1996) are probably the best places to start, but even these books are overly simplistic and incomplete. Most survey projects will also need to consult the wider literature on survey design and methodology and data analysis for more detailed information related to the specific concerns of their project.
Answers to True/False Questions

The answer to all of the questions is false:

1. Once a population reaches a certain size, the size of the sample necessary to estimate opinions within a few percentage points is fairly constant. A carefully selected sample of about 1200 people is sufficient to determine the opinions of the entire U. S. population with a sampling error of plus-or-minus 3%.

2. Since telephone directories don't include people who have unlisted numbers, people without phones, and people whose listings have been changed or added since the last publication, they cannot be relied upon to provide a random sample. Better choices for choosing a sample of telephone numbers are random digit dialing and add-a-digit dialing. See Chapter 5 of Salant and Dillman (1994).

3. Actually, it is essential for survey questions to be grouped categorically to minimize the burden on the respondent and to demonstrate that careful thought went into the design of the questionnaire. In addition, in some cases an alternate ordering of identical questions can change responses by as much as 30%, so question ordering requires careful consideration.

4. Although posting a survey on the web can give you access to a huge audience, this audience is not representative of the general population. Even if you wish to generalize only to Web users, this strategy does not allow you to determine the response rate to your survey, a step which is absolutely necessary to be able to interpret survey results. See Section IV.

5. It is not acceptable practice to keep adding names to your sample until you get a sufficient number of respondents, since this results in a very low response rate. The correct approach is to adopt methods and procedures that will ensure a large percentage of your original sample will respond.

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CHAPTER 11

INTRODUCTION TO INTERVIEWING TECHNIQUES

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1. Introduction

When researchers new to a subject area come across an important question that they don't know the answer to, their first reaction is often to interview people who (hopefully) do know the answers. Since these interviews seem like the everyday conversations that we are all familiar with, they are often conducted in a casual manner with little advance preparation. The results of such casual efforts, however, are almost always disappointing.

What these researchers fail to realize is that a research interview -- an interview that can provide reliable evidence to answer a research question or to help solve a social problem and that can be defended against skeptical critics -- bears little resemblance to an ordinary conversation. In fact, some of the best techniques for conducting valid, reliable interviews directly violate the conventions of everyday conversation. For example, in ordinary conversation it is considered impolite to remain silent after someone has finished speaking, yet an interviewer must at times do exactly this in order to encourage participants to elaborate on what they are saying. Also, in some interviews protocol requires the interviewer to ask questions that participants have already answered, which almost never happens outside of interview studies due to social norms that dictate that conversations should not be repetitive.

Because research interviews require the use of skills -- for example, careful listening, noting nonverbal cues, monitoring the progress of a conversation while participating in it and taking notes -- that aren't typically acquired from our experience with everyday conversations, they require careful planning and preparation. To conduct interviews that are useful for research purposes, researchers must, among other things, develop as much expertise in relevant topic areas as possible so that they can
ask informed questions; consider very carefully such questions as who to interview, how many people to interview, what type of interview to conduct, and how the interview data will be analyzed; and learn established techniques for ensuring that the interview data are unbiased (even seemingly subtle factors like the interviewer's mood, personality, dress, and manner can alter participants' responses and bias the data!).

The aim of this paper is to introduce you to what social scientists know about how to design, implement, and analyze an interview study and to explain how these techniques can improve the quality and utility of IQPs that employ interviews as either the main focus of the project or as a complement to other methods of data collection or analysis. As is appropriate for an introductory monograph that is intended to be portable and therefore relatively brief, the scope is limited and only three main interviewing techniques -- in-depth qualitative interviews, focus groups, and standardized interviews -- out of a wide variety of available alternatives are discussed. It is therefore recommended that students use this paper as a starting point to a more detailed exploration of the literature on interviewing techniques. Suggestions for where to begin this process are included in Section IX.

II. When Interviews Are Appropriate

Interviews can be used effectively for a wide variety of purposes, for example: to learn about cultural customs, to evaluate the effectiveness of an educational or social program, to document expert opinions, to explore people's reactions to important events in their lives, to develop oral histories of important historical events, or to create life histories of interesting or influential people. However, interviews are not appropriate for all research questions and problems. For example, it makes little sense to conduct interviews to collect information that is easily available from published books, reports, records, or documents. This is due to two main reasons. First, interviews are time consuming for both the researcher and the interviewees, and interviewees may become uncooperative if they conclude that their valuable time is being wasted. Second, interviews represent the off-the-top-of-the-head thoughts of people who have at most an hour or two to think about their answers, and they are bound to occasionally forget things or make mistakes. In contrast, published work can represent weeks, months, or years of thought and analysis and is therefore usually much more reliable and complete. Interviews, like other techniques in which researchers interact closely with their subjects, are also limited by the fact that the researcher's behavior or mere presence can alter a subject's thoughts and behaviors. If it is important for the success of the project that this possibility be eliminated, less intrusive methods, such as naturalistic observation or the content analysis of existing documents, may be preferred.
Interviews will be most successful and useful when the information needed for a research project can be obtained in no other way. This may hold true when you need a rich, detailed picture of people's experience and the meaning they attach to it; when your topic is so new or understudied that published information is unavailable or inadequate; or when, because the questions of interest are sensitive, technical, or complicated, your physical presence is required to guide people through the process of answering questions. Use of personal interviews should also generally be reserved for situations when detailed, narrative information is required. If simple factual information or quantitative judgments are desired, they can be collected much more efficiently and accurately through a telephone or mail survey.

III. Choosing the Right Interview Method

There are many different established interview methods that can yield useful results in at least some situations. However, for brevity's sake, in this paper the discussion will be restricted to three broad categories of interview methods that differ primarily in the extent to which they are "standardized" (that is, the extent to which the exact same questions in the same order are asked to each participant) and whether the interviews take place in an individual or a group setting. These distinct interview methods are in-depth qualitative interviews, focus groups, and standardized interviews, and their strengths and weaknesses are detailed below.

In-depth qualitative interviews are flexible and exploratory interviews in which the researcher adjusts later questions depending on how the interviewee answers earlier questions in order to clarify the responses, to follow promising new lines of inquiry, or to probe for more detail. The interview style is unstructured and conversational, and the questions asked are generally open-ended and designed to elicit detailed, concrete stories about the subject's experiences. The purpose of such interviews is not to identify objective truth or to conclusively test hypotheses but to help the researcher understand the experiences of the participants and the conclusions the participants themselves have drawn from them. In-depth qualitative interviews are most appropriately used when a rich, detailed, holistic picture is needed of people's experience and how they interpret it; when you are interested in explanations of thoughts or behaviors that are rooted in situational or contextual factors; or when, perhaps because your study is exploratory in nature, you need a method that is flexible and can be changed as necessary as the study proceeds. Qualitative interviews are not appropriate when answers are sought only to simple, factual, or quantitative questions. The primary advantages of qualitative interviews are the flexibility they
offer and the rich, detailed data they can provide. However, these advantages, as is true for all social science methods, are not gained without cost. There are two main disadvantages associated with qualitative surveys. First, due to the large amount of time and effort they involve, qualitative interviewers can't usually study a very large or random sample of people. This makes it very difficult to claim that the findings of such a study can be generalized to other groups of people that did not participate. Second, since the interviewer in a qualitative interview takes a very active role in determining what data are collected, there is a higher probability that he or she may inadvertently bias the results of the study.

Focus groups are a variation of in-depth qualitative interviews in which several people are interviewed together in a flexible and exploratory group discussion format. In focus groups the emphasis is on interactions between participants rather than between the researcher and the participants, and the researcher adopts a role that is more like a moderator than a questioner. The purpose of focus groups is to explore people's ideas in a public setting so that you can observe how they react to each other's ideas, when they challenge each other's views, and how their opinions are formed. Focus groups are most appropriately used when it is important to obtain opinions after they have gone through a public process in which they are shared with and commented on by peers. This may be important, for example, when you are studying people's reactions to a new program, policy, or product for which people's opinions are not yet fully formed — in such cases the focus group serves to accelerate the natural social processes by which individuals compare opinions with each other before making up their minds. Focus groups are not appropriate unless you are studying a topic that can be expected to generate a lot of discussion and lively debate. They are also not recommended for studying sensitive topics that people will be reluctant to discuss in public. The primary advantages of focus groups are that they tend to be more convenient and less time-consuming for both researchers and participants and they are less likely than individual interviews to be subject to bias introduced by the researcher, since the researcher takes a less active role in guiding the discussion. However, the researcher's inability to direct the discussion can at the same time decrease the likelihood that the desired information is gathered and make data analysis more difficult. Two further disadvantages of focus groups are (a) like in-depth interviews they do not allow for findings to be generalized to larger populations and (b) the public setting in which the discussions take place may lead people to give different answers than they would have if individual interviews had been conducted.

Standardized interviews are rigid, structured interviews in which the interviewer reads from a script and deviates from it as little as possible. All interviewees are asked the exact same questions in the exact same order, and most, but not necessarily all, of the questions are fairly simple and elicit relatively
brief answers. Standardized interviews are designed to provide the researcher complete control over all aspects of the interview, to rigorously test hypotheses, and to provide answers that can be expected to hold true for larger populations beyond those individuals who were studied. Standardized interviews are most appropriately used when a researcher desires answers to the relatively simple or factual questions that are typically handled by telephone or mail surveys, but, perhaps because the topic is technical or complex or the participants cannot be reached by mail or telephone, personal interviews are the only option. Standardized interviews are not appropriate when a flexible method is needed or when a researcher wants to capture the rich, detailed data that can be gained, for example, by qualitative interviews. The primary advantage of standardized interviews is that they address two of the main limitations of qualitative surveys: (a) since both the interview process and data analysis are substantially less time-consuming, researchers are more likely to be able to study large enough samples of people to allow findings to be generalized to larger populations; and (b) since procedures are highly standardized, the possibility of the results being influenced by interviewer bias is substantially decreased. Of course, these advantages are gained by giving up the main advantages of qualitative interviews, namely, the ability to capture rich detail and the flexibility to change procedures and topics as needed.

The remainder of this paper will focus on describing and comparing the three basic interviewing techniques. Sections IV and V describe how to gain the cooperation of interviewees and how to conduct interview studies in an ethical manner, procedures which are relatively uniform no matter which interview method you choose. Sections VI, VII, and VIII then go into the three main interviewing techniques in detail, covering the basic topics of how to select the number and identity of participants, how to plan and implement the interviews, and how to analyze the resulting data.

IV. Getting the Interview

No matter which type of interview method you choose, you will need to take the same basic steps to get your chosen subjects to agree to be interviewed and to follow through on that commitment. The first step is usually to send potential interviewees a letter that briefly describes your research project, why they have been chosen, and why participating in your study is worth their time and effort. The letter should be professional in content and appearance, convey to potential interviewees that you are interested in their experiences and opinions, reassure them that the interview will be easy and convenient for them, and promise that their responses will be kept strictly confidential.
The introductory letter should also indicate to potential interviewees when and how they will hear from you again to discuss their participation. This second contact, the purpose of which is to obtain a formal agreement to participate and to work out the logistics of the interview, may be conducted either via telephone or a brief, in-person visit. However, you should keep in mind that in-person contacts have several advantages that telephone contacts do not, for example, they allow the researcher to observe the conditions where the interview will take place as well as make it easier to determine whether or not the person is appropriate for your study. Before this second contact is made you should have thought carefully about how you want to answer the questions that people tend to ask when deciding whether or not to participate in interviews. Typically people will ask questions about any organizations that are sponsoring the research, about logistics such as how long the interview will take and how the confidentiality of responses will be ensured, about your qualifications to conduct the research, about how the research findings will be used, and about whether they or someone else is the most appropriate person to participate. You should be prepared to answer these questions in a way that will reassure them and encourage them to participate. During this contact you should also explain the logistics of how the interview (and the subsequent analysis and reporting of it) will be conducted, as well as obtain permission to record the interview (which is recommended if at all feasible). In addition, if somebody they know nominated them for the project, you should let them know — this will also encourage participation, since people generally like to do favors for their friends, colleagues, and associates.

Even after someone has agreed to participate, there are steps you should take to make sure they cooperate fully and complete the interview. First, you must convince them that you know what you're doing, that you are knowledgeable about how to conduct an interview study, and that you are knowledgeable (perhaps as a result of a review of relevant literature) about the topics covered by the interview. If interviewees get the impression that you don't have the appropriate background to understand what they are saying and learn from it, their cooperation may be withdrawn. Second, the interview must be conducted in a professional manner, from arriving and leaving on time to conveying professionalism through your voice, behavior, and dress.

V. Ethical Considerations

Researchers who conduct qualitative, focus group, or standardized interviews have the same obligations to protect the welfare of the people they study as do any other researchers who study human behavior. The following four topics deserve careful consideration before embarking on an interview project:
1. Researchers are obligated to obtain the "informed consent" of the subjects of their research. This means that researchers should avoid any deception or errors of omission and be completely honest when informing participants about the purpose of the study, the procedures that will be followed, and the uses of the interview data. Participants must also be informed of their basic rights, including the fact that they may withdraw their consent at any time or may refuse to answer any particular questions if they wish.

2. Adequate procedures must be planned and implemented to ensure that the confidentiality of participating individuals and/or organizations is maintained before, during, and after the study, unless they have signed a waiver allowing their names to be used. This means, for example, that any public report of the study must be gone over carefully to ensure that the identity of the participants cannot be inferred. In some circumstances this may necessitate the use of pseudonyms.

3. Any promises made to participants must be kept. It is common practice in qualitative interviews, for example, to promise interviewees a chance to review the transcripts and/or summaries of their interviews for accuracy. Common courtesy also dictates that interviewees should receive a letter thanking them for their participation.

4. It is not impossible that the interview process could have negative or even harmful effects on the interviewees in some cases. For example, people may disclose information that they regret sharing later on. Also, sensitive topics can induce stress, anxiety, or a strong emotional reaction in the participants. Researchers are obligated to carefully weigh these possible negative effects against the positive benefits of conducting the study.

VI. In Depth Qualitative Interviews

A. Selecting Participants

Since qualitative interviews are so time-consuming to conduct and analyze, only a limited number of people can be interviewed. Thus, participants should be carefully selected for their special expertise or experience, and it is important to identify and seek the participation of the people who will be the most informative and helpful rather than interviewing only those people who are the easiest to access. It is also important to keep in mind that the criteria for selecting potential interviewees may change as the study proceeds. For example, at the start of an interview study it is generally important to interview individuals who can present "the big picture" so that all of the important subtopics can be identified. At later stages of the process, it may be more appropriate to interview
people who have more detailed or specialized knowledge rather than generalists. One of the best ways to find such people is to ask for recommendations from those early interviewees who have been particularly helpful.

The obvious drawback to this strategy of selecting a limited number of interviewees who have special characteristics is that it is not possible to ensure that the final list of interviewees is representative of the larger category of people from which they were drawn. It is therefore a good strategy to deliberately seek out the widest possible range of opinions and experience (a technique called “maximum variation sampling”) so that your study cannot be criticized for only interviewing people whose thoughts conform to the researcher's expectations or hypotheses.

B. Deciding How Many Interviews to Conduct

Since qualitative interviews do not attempt to gain high enough numbers of participants to allow hypotheses to be tested for statistical significance, the appropriate number of interviews to conduct is determined by the subjective judgment of the researcher. What this means is, you stop interviewing when, in your opinion, you have obtained a complete understanding of your chosen topic. If in your last few interviews the participants simply repeated information you had already heard from others, it's probably time to stop.

C. Preparing to Interview

Since qualitative interviews are intended to be flexible and adaptive, they cannot be planned out in specific detail in advance. However, it is possible and, in fact, necessary to prepare in advance a list of important topics so that you can refer to them during the interview; otherwise, you may forget to cover them. It is also necessary to make informed decisions about how to ask or phrase questions related to these topics and about what level of detail you would like to achieve in the answers to them before you start interviewing.

Careful thought should also be given to how to organize the interviews. Although qualitative interviews are flexible, they should not be unorganized or random. Effective qualitative interviews are typically divided into three stages. In the first stage, the goal is to establish the background of the interviewee. You should try to get them to talk about themselves, describe the experience they have that is relevant to the topic at hand, and explain the history of how they came to be where they are today. In the second stage, the focus shifts to the details of their present experience that are relevant to your topic. You might ask them, for example, to “reconstruct a typical day” or “talk about their relationships with the people they work with.” Finally, having reflected on their background
and experience, they will be ready in the third stage to report on the meaning their experience has for them. In this third stage typical questions are "what have you concluded from all this?" or "what sense does this make to you?" This basic tripartite structure should be followed for each interview to ensure that participants render judgments and opinions only after careful reflection.

You should also have done your homework on the topics of the interview, which usually requires a thorough review of relevant literature. Qualitative interviewing requires you to have a good idea in advance of what information you need and to think fast in order to adjust your questions depending on what the interviewee says - these goals can only be achieved if you have gained a command of the relevant topic area and associated terminology.

Finally, novice interviewers are well-advised to conduct a "practice" interview or two before the study begins in earnest. Qualitative interviewing requires the interviewer to do several things effectively all at once, including listening intently, monitoring the progress of the interview, picking up nonverbal cues, and remembering what has already been said. It is a difficult task that can only be mastered through practice and experience.

D. The Interview Process

Qualitative interviews place several demands on the interviewer. For example, the interviewer must give the interviewee their rapt attention while taking notes, following an agenda, monitoring the time, paying attention to nonverbal cues, and making decisions about whether to probe for more detail or move on to another question, all at the same time. Good qualitative interviewing is a difficult skill that is best acquired through practice and experience, rather than reading about it. However, as you begin this process it might be helpful to pay attention to some of the collected wisdom of social science researchers. The following are some of the most important "pointers" for novice interviewers culled from the literature on qualitative interview techniques:

1. Qualitative interviewing requires concentrated, rapt attention, so that you can follow up on interesting comments, detect when interviewees are giving answers meant for public consumption rather than their true opinions, and monitor the progress of the interview. It is therefore important that the interviewer not dominate the interview by talking too much but instead focus on listening.

2. Yes/no or other questions that can be answered briefly are not appropriate for qualitative interviews. Instead, you should ask open-ended questions, that is, questions that require a
detailed narrative answer. For example, you might ask interviewees to “walk you through a typical day” or “tell you a story about a particular event that illustrates what they’ve been talking about” or “trace a story back to its very beginning.”

3. It is important to give interviewees appropriate clues as to how detailed you would like their answers to be. If you tell them how many topics you plan to cover in the allotted time frame, listen carefully, and ask for further detail when appropriate at the beginning of the interview, they will probably catch on.

4. The questions in a qualitative interview should logically follow from previous questions. Rarely is one question on a topic enough – you must be prepared to follow up whenever you’re not sure about what the person is saying by asking for clarification, details, and examples.

5. It is important to avoid leading questions, that is, questions that because of the way they are worded or phrased indicate to the interviewee what sort of answer the researcher expects to hear.

6. As a general rule, the researcher should interrupt the interviewee as little as possible. Things they mention that cry out to be followed up on can be noted and brought back up at a later point. However, if the interviewee strays drastically off course, it is appropriate to guide them back to the topic at hand.

7. Qualitative interviewers have to learn to tolerate silence. It is important not to get impatient, but to give participants a chance to think about what they want to say. It is a natural human tendency to fill in pauses in conversation, and if the researcher can avoid doing so the interviewee will often fill the silence with more information.

8. The interviewer should try to strike a balance between being formal versus casual. If the interviewer behaves too formally, the participants may not open up to them. However, if the interviewer behaves too casually, the participants may not take the interview seriously and may stray off topic.

9. Finally, it is important to leave the interview on a positive note and to get the interviewee to agree to be contacted again in the future if necessary. You might need, for example, to contact them at a later date to clarify something they said or even to ask new questions that were raised by subsequent interviews.

E. Reducing and Analyzing the Data
The goal of a qualitative survey is to develop explanations and theories that are carefully grounded in the evidence, that is, the interview data. These data must therefore be recorded and preserved in some form to allow the interviewer (and perhaps other members of the research team) to review and analyze them long after the interview is over. For a variety of reasons, tape recording and transcribing the interviews verbatim is far and away the best strategy for preserving interview data:

1. It is just too difficult to do all the things you need to do during a qualitative interview and take detailed notes as well.

2. It is important to keep data collection and analysis separate. Conclusions should not be drawn until all of the data are in, and taking notes by hand during the interview requires the researcher to make judgments about what's important and what's not during the interview.

3. Taking notes efficiently requires the researcher to edit and rewrite the interviewee's comments, which may result in their meaning being inadvertently altered.

4. Like any other research effort, it is desirable to keep the original data complete and intact so that both you and other interested researchers can refer to it if necessary.

If for some reason tape recording an interview is not possible, an alternative strategy is to have two researchers participate in the interview: one who focuses exclusively on conducting the interview and a second who takes over the task of taking detailed notes.

Recording and transcribing interviews results in an unwieldy amount of verbal data. It should therefore come as no surprise that one of the main purposes of qualitative interview analysis is to reduce the amount of data to a more manageable level. The goal is to identify and extract the most important, meaningful, and interesting parts of the interview text. This should begin as a process of "discovering" what's in the material, rather than starting out with definite hypotheses in mind. In qualitative studies this process of data reduction and analysis is subjective, and to convince readers of your report that your analysis is appropriate and defensible you will have to (a) demonstrate that it is based on a careful reading of the interview texts; (b) make it clear that you explored any data that were inconsistent or contradictory across subjects; and (c) report in detail on how you carried out your analysis so that readers can judge its appropriateness for themselves.

A good way to get started in qualitative data analysis is to read carefully through each interview and underline or circle those items that you think will prove to be the most important or meaningful. You should then develop a "profile" of each
interviewee, that is, a summary of the interviewee's background, experience, and opinions. Whenever possible, interviewee's opinions should appear in these profiles in their own words, to avoid the possibility that rewriting them may change their substance or emphasis.

Once each individual interview has been summarized, attention generally turns to making comparisons across individuals. This requires the researcher to return to the interview transcripts and review them looking for similarities and differences and patterns and thematic connections in the data. Each coherent interview segment should be given a code number to indicate the concept, category, theme, or argument it relates to. These segments can then be copied and separated from the transcripts (with either real or electronic scissors) and put back together thematically to serve as the raw material for an analysis of the general findings of the study and their implications for policy or decision making. Data reduction can be achieved by noting redundancies in the data and discarding all but the most interesting and compelling statements concerning a particular issue or theme. In some cases it may be desirable to note quantitative aspects of the interview data, for example, the number of participants that express a particular concern or who shared a similar experience.

It is a good idea, when practical, to give interviewees the opportunity to review their transcribed interviews and the profiles and other sections of the project report that are based on them as soon as they are available. This will give the participants a chance to catch any errors in the material and to express their opinion as to whether the report accurately captures what they were trying to say. If they express confidence that their transcripts and profiles are accurate, this will in turn increase the confidence that readers of your report will have in your work.

VII. Focus Groups

A. Selecting Participants

Like qualitative interviewees, focus group participants are typically selected for their special expertise or experience, and it is desirable to seek out a wide range of views to defend your study against charges of selection bias. However, the group setting of focus groups means that the participants must feel comfortable talking openly and honestly with each other, which requires that each group be somewhat homogeneous in background and experience. Therefore diversity should generally be achieved by running a diverse set of relatively homogenous groups rather than trying to achieve diversity within a group.
There is, however, one exception to this principle of structuring homogeneous groups: if some of the participants are friends or know each other very well it is best to put them in separate groups. This is because people who are very familiar with each other's views will be more likely to leave their questions and comments unstated rather than bringing them out in the open where they can be observed by the researcher.

B. Deciding How Many Interviews to Conduct

The criteria for when to stop running focus groups is the same as that for qualitative interviews: you quit when you are no longer learning anything new. This typically requires a minimum of 3 to 4 groups -- but if the group members are heterogeneous (i.e., have diverse backgrounds and experiences) more than 4 groups may be required. It should be noted that running just one focus group is never enough, since the results of a single group could be due merely to idiosyncracies of the individuals in that particular group.

As far as the appropriate size for an effective focus group, the general recommendation is between 6 and 10 individuals. This is a large enough size to provide some diversity of opinion and keep the discussion manageable yet not so large that people don't have a chance to express themselves.

C. Preparing to Interview

Focus groups, since the researcher adopts the role of a moderator rather than an interviewer, are even more flexible than qualitative interviews and thus even fewer details of the interaction can be planned out in advance. It is still important to review relevant literature to acquire expertise on the topic of study and to come to the session with a list of half or dozen or so carefully crafted and ordered discussion topics. As in qualitative interviews, these questions should focus on the background and context of the participants and their specific, detailed experiences. In focus groups it is generally a good idea to minimize the emphasis on collecting opinions. In a public setting people may be reluctant to challenge each other's opinions but will usually be quite willing to contribute contradictory stories or experiences.

Beyond these basic considerations the main design choice faced by the focus group researcher is the appropriate level of moderator involvement. If your study is exploratory or you are particularly interested in finding out what participants think is interesting or important, you may want to minimize your involvement in the focus group process to allow this information to emerge naturally. If, on the other hand, you have prepared a
lengthy agenda of important questions and want to be sure to cover all of them, you may instead want to exercise substantial control over the group discussion. Of course, like most methodological choices in social science, the benefits of each approach come with a cost. When the moderator takes a hands off approach, there is an increased chance that the discussion will be disorganized, wander off topic, and fail to cover important topics; when the moderator instead exerts substantial control over the content and direction of the discussion, there is an increased chance participants will change what they say in order to conform to the expectations of the researcher.

D. The Interview Process

Focus groups are not, in a strict sense, interviews at all. The researcher's job is not to interview but to act as a moderator and to facilitate the discussion of others without being an active participant. (If at all possible, the same moderator should be used for all of the groups, so that group differences cannot be attributed to differences in the moderator's style or behavior.) These discussions typically take place around a large circular or rectangular table, which encourages interaction and allows participants to see who they're talking to.

The moderator should begin the discussion by establishing the ground rules, which typically include a request that only one person speak at a time and that participants do not engage in side conversations with only part of the group. You should explain your role to the participants, tell them you are there to learn from them, and that it is important that everyone participate. To get things going, you might ask each person to introduce themselves and describe their background. Then you should introduce the first topic and observe what happens.

The goal of the moderator should be to contribute to the proceedings only when necessary. Some groups may work very well, covering all of the topics with everyone participating. Other groups may need a little prodding to stay on track. As in a qualitative interview, you must listen carefully so that you can direct the discussion when necessary and resolve any problems that crop up. You may need to intervene, for example, if the discussion strays into irrelevant topics, if people run out of things to say, if one or a few people are dominating the conversation, if one or more people are not participating, or if people are talking at a very general level rather than sharing specific experiences. One technique that is often effective for generating discussion is to ask the participants to ask questions of each other.
At the end of the focus group it is a good idea to ask each group member to summarize their thinking on the topic at hand. This will allow you to assess what effect (if any) the group discussion had on the individuals.

E. Reducing and Analyzing the Data

Like qualitative interviews, focus group discussions should be tape recorded if at all possible so that data analysis can be based on a detailed transcript of the proceedings. In addition, since it is sometimes difficult to tell who is speaking on a recording, a research team member should take note of who is talking when during the discussion so this information can be added to the transcript of the recording.

Once the data are transcribed, data reduction and analysis proceeds along similar lines as the analysis of individual qualitative interviews. The main difference is that in focus groups, the group serves as the unit of analysis rather than the individual. This means that profiles are developed for each group, not each individual, and comparisons are made between groups, not within a group.

VIII. Standardized Interviews

The design, implementation, and analysis of standardized interviews are very similar to that of mail and telephone surveys (although the increased personal contact between the researcher and the participants adds another layer of complication). The treatment of standardized interviews in this monograph is therefore relatively brief, and readers are referred to the relevant sections of the IGSD document titled "Introduction to Survey Design and Methodology" when appropriate (hereinafter referred to as the IGSD Survey Manual). For example, Section V of the IGSD Survey Manual discusses how to choose from among the three main types of standardized surveys.

A. Selecting Participants

Since the main goal of standardized interviews is to provide answers to questions that can be generalized to larger groups of people beyond the interview study, participants should be sampled randomly from the population of interest. This requires the construction of an unbiased list of members of the target population and an unbiased decision rule for selecting people from the list to interview. The technique of simple
random sampling is described in Section III of the IGSD Survey manual.

In addition to choosing participants randomly, a strong effort must be made to ensure that a high percentage of people selected in the random sample actually end up participating. That is, you must achieve a high "response rate" to your requests for interviews. The importance of high response rates and techniques for achieving them are described in Section IV of the IGSD Survey Manual.

B. Deciding How Many Interviews to Conduct

Standardized interviews are designed to allow for results to be tested for statistical significance. Thus a comparatively large number of people must be interviewed. The number of interviews conducted in a standardized survey is not flexible, as it is in a qualitative interview, but should be determined before data collection begins. This is because, while adding people to the study at a late date increases the sample size, it typically decreases the response rate below acceptable limits.

Choosing on an exact number of standardized interviews to conduct requires a statistical calculation that depends on the degree of variation in the population and how much sampling error is acceptable. Directions for making this calculation appear in Section III of the IGSD Survey Manual.

C. Preparing to Interview

To achieve standardization in an interview requires a great deal of advance preparation. The entire interview, including introductory comments, must be scripted, and even those aspects of the interview which can't be anticipated, such as the need to answer requests for clarification, must be standardized as much as possible. Writing valid, reliable, and unbiased standardized survey questions and organizing them into an effective interview script is a complicated art and success can only be achieved by subjecting the script to a rigorous process of review and revision. Tips for writing good questionnaires can be found in Section VI of the IGSD Survey manual. Sections VII and VIII of that document also discuss questionnaire design and pretesting, respectively.

A carefully constructed interview script, however, is necessary but not sufficient to prepare to conduct standardized interviews. The style and quality of delivery by the interviewer can influence how people answer the questions, and therefore the delivery must be uniform across participants. This means that, before data collection begins, interviewers should practice reading the script until
they can deliver it with consistent quality, emphasis, and pacing.

D. The Interview Process

The researcher's goal during a standardized interview should be to say as little as possible, other than reading the interview script exactly as it is written. This requires, for example, that even when a participant has answered a question as part of a previous answer, the question must be read and answered again. Also, if a participant begins to volunteer an answer before the entire question is read, they should be asked to wait until they've heard the entire question.

Of course, deviations from the interview script are often necessary to provide clarification or feedback to the participant or to probe for more detail when the answers are too general to be useful. Suggestions for accomplishing these tasks while ensuring standardization are detailed below:

1. Clarification. The first strategy to try when participants ask for a question to be clarified is simply to repeat all or part of the question. If this doesn't work, the interviewer should be able to draw upon a prepared list of definitions and stock answers to frequently asked questions.

2. Feedback. It is important for the interviewer to provide their subjects feedback when they are doing well in order to encourage them to listen carefully and to give thoughtful answers. This feedback may be in the form of a nonverbal smile or nod or a short encouraging phrase. Verbal feedback should be selected from a prepared list of stock phrases such as "That's useful information" or "That's the type of answer we're looking for" or "Thank you, that's helpful" to ensure that the feedback is uncorrelated with the content of what the participant is saying. However, care should be taken to ensure that positive feedback is given only for satisfactory performance.

3. Probing. If a participant's performance is unsatisfactory, the interviewer must employ unbiased techniques to encourage answers that are more complete, appropriate, and thoughtful. These strategies of "probing" for more information may be just a pregnant pause to encourage the person to fill the silence or a direct request for further information. Verbal probes should, like feedback phrases, be chosen from a stock list of phrases such as "Could you explain what you mean by that?" or "Can you tell me anything else about ________?"

E. Reducing and Analyzing the Data
Data reduction is much less of an issue for standardized interviews than for qualitative interviews, since much less data are collected. Standardized interviews generally ask questions that call for relatively short, simple, or quantifiable answers which the interviewer writes or marks on a copy of the interview script during the interview. So long as the interviewer takes the time to write everything down accurately (including any probes or other deviations from the interview script), it is not usually necessary to record the interview sessions.

The main goal in the analysis of standardized interview data is to quantify the data and subject it to statistical analysis so that hypotheses can be confirmed or disconfirmed and the degree of error associated with population estimates can be determined. An introduction to this process of statistical data analysis can be found in Section XII of the IGSD Survey Manual.

IX. For Further Information

This paper has described the basic steps of planning, implementing, and analyzing three different types of interview studies that are appropriate in different situations: qualitative interviews, focus groups, and standardized interviews. However, if you choose to adopt one of these methods as part of your IQP, you should also seek out additional information on the method you have selected. The following sources are recommended as good places to begin this learning process:

A. Qualitative Interviewing


B. Focus Groups


C. Standardized Interviews


PART VI

QUANTITATIVE METHODS FOR IQPs:

CHAPTER 12: INVESTMENT DECISIONS - LIFE CYCLE COSTING

CHAPTER 13: REGRESSION ANALYSIS

CHAPTER 14: ECONOMETRIC MODELLING

CHAPTER 15: SYSTEM DYNAMICS

Prepared
for

The Interdisciplinary ands Global Studies Division

by

Douglas W. Woods
SS&PS
General Introduction

Part VI reviews quantitative methods for IQPs in four broad areas: Investment Decisions and Life Cycle Costing (1), Regression Analysis (2), Econometric Modeling (3) and System Dynamics (4). These areas were chosen because of their relevance to interactive project work. Past experience has shown that the need for these techniques arises more frequently in IQP's than most other types of quantitative analysis.

Of the four topics discussed here, the last three listed above are presented briefly, with just enough information to enable the reader to understand the purpose of the methodology, the types of problems in which its application may be required and to a limited extent, how to use it. Readers who need to employ these techniques can obtain the necessary additional information from the references listed at the end of each section.

The aim of Chapter 12, which discusses Investment Decisions and Life Cycle Costing, however, is more ambitious. The reader willing to invest several hours studying this section should acquire the ability to analyze thoroughly the financial aspects of most types of investment decisions. The reader should come away with an understanding of how these methods of analysis work, why they yield correct decisions and how to apply them. This chapter is accompanied by an available computer disk containing electronic spreadsheet solutions to a set of sample problems. Many readers will find that these solutions can be applied to their own problems simply by changing the input data.
CHAPTER 12

INVESTMENT DECISIONS - LIFE CYCLE COSTING

Introduction (12.1)

The analysis of investment decisions and life cycle costing are closely related methods for evaluating investments involving initial expenditures for equipment, installation, service and/or training etc. that will have future benefits or will impact future costs. In business financial management the process of evaluating and choosing from among such investments is termed capital budgeting. In engineering economic analysis this process is referred to as "economic evaluation of investment proposals" or as "comparison or selection of alternatives". All of these terms refer to a common body of analytical techniques that are essential tools for investment decision making by government, private agencies, homeowners or business firms. Any IOP or MQP which recommends or evaluates courses of action involving investments requires the use of these techniques to support its conclusions.

The essence of an investment is a sacrifice now in exchange for future benefits. In a typical investment decision the question is, should a project be undertaken? Do the future benefits from doing so outweigh the initial costs? Examples would be a decision by a state DPW to construct a new highway or a power company to build a hydroelectric plant. The benefits may be in the form of additional future income or revenue or may be intangible and nonpecuniary in nature. (This chapter deals only with the analysis of the quantifiable, financial aspects of investment decisions. Methods exist for assessing intangible costs or benefits, in some cases quantifying them, but are beyond our present scope. They are discussed in the literature referenced at the end of the chapter.)

In life cycle costing, the issue is how best to accomplish a given task - what is the least cost method, taking into account both the initial outlay required and future operating costs. An example would be determining which system among several alternatives for heating a new house would be most economical over the system's entire operating life. Life cycle costing also involves investment decisions, in the sense that some of the methods under consideration will require larger initial outlays but achieve lower future costs than others.

Because of the need to consider relevant intangible benefits (and costs), the analysis of investment decisions is broader in scope than life cycle costing. What both techniques have in common is the requirement that future costs (life cycle costing) or net benefits (investment decisions) must be measured on a common scale along with the initial outlay. In doing so, account must be taken of what is called the "time value of money." The latter refers to the fact that money in hand right now could be invested elsewhere, i.e. in stocks or bonds, at a positive rate of interest. That
money with accumulated interest would amount to more in the future than it does right now. Consequently, any money to be received or spent in the future is equivalent to a smaller sum of money to be received or spent right now.

This chapter focuses on the various methods available for taking account of the time value of money, the interest factor, in evaluating investments. Use of these methods (frequently, referred to as discounted cash flow or DCF techniques) is not optional. Failure to employ them will result in erroneous economic evaluations and incorrect decisions.

Illustration of Compound Interest (12.2)

Interest that might have been earned (or will be owed) accumulates on a compound basis. That is, additional interest will be earned (or owed) on interest that remains outstanding or is reinvested. Thus, the interest factor required to evaluate cash flows occurring at different times is based on the concept of compound interest.

Consider the following illustration: We lend out $L at an annual compound rate of interest of k%. How much will the borrower owe us at the end of each future year assuming that interest is not paid annually, but rather accumulates until the end of the loan? (Note that the interest rate k is stated as a percent, but is used in the interest calculations below as a decimal fraction.)

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amt Owed</td>
<td>L</td>
<td>L+Lk =</td>
<td>L(1+k) + L(1+k)k =</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L(1+k)</td>
<td>L(1+k)(1+k) =</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>L(1+k)^2</td>
</tr>
<tr>
<td>Year</td>
<td>3</td>
<td>...</td>
<td>n</td>
</tr>
<tr>
<td>Amt Owed</td>
<td>L(1+k)^2 + L(1+k)^2k =</td>
<td>L(1+k)^n</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L(1+k)^3</td>
<td></td>
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</tr>
</tbody>
</table>

At the end of year 1 we are owed the original principal L plus the interest Lk. That entire amount L+Lk or L(1+k) remains outstanding in year 2 so that at the end of that year we are owed the new principal L(1+k) plus the interest L(1+k)k. Together these total L(1+k)^2. Similarly, the amount owed at the end of year 3 is L(1+k)^3 and any year n is L(1+k)^n. The factor (1+k)^n is termed the future value or compound value interest factor FVIF_{k,n} (or CVIF_{k,n}). The effect of compounding is very powerful. For example, if L=$1000 and k=10%, the amount owed at the end of year 20 is $1000(1.1)^{20}= $6727 versus $3000 without compounding.
The Concept of Present Value (12.3)

The most common way of evaluating the cash flows generated by an investment is to use the time value of money measured as a compound rate of interest to determine what future cash flows are equivalent to in terms of cash in hand right now. That equivalent value is termed present value or present worth. For example, the present value, \( P \), of the amount \( F_n \) to be received at the end of \( n \) years is given by

\[
P = \frac{F_n}{(1+k)^n},
\]

where \( k \) = the annual compound rate of interest at which the investor can lend or borrow.

The term \( 1/(1+k)^n \) is called the present value interest factor (PVIF\(_{k,n}\)). The amount \( P \) is the present value of the future cash flow \( F_n \) because this future cash flow can be converted into \( P \) dollars in hand now by borrowing \( P \) at the rate of interest \( k \). By the end of year \( n \), the amount \( P(1+k)^n \), then owed, could be repaid using the cash flow \( F_n = P(1+k)^n \).

Evaluating Investments Using Present Value - NPV & PI (12.4)

Any investment opportunity can be evaluated by using the present value interest factor \( PVIF_{k,n} = 1/(1+k)^n \) to determine the present value of all future cash flows generated by the investment. Consider an investment with the following cash flow pattern over time.

Investment Opportunity - Cash Flow Pattern

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>...</th>
<th>( n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cost:</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future annual net cash flows:</td>
<td>( F_1 )</td>
<td>( F_2 )</td>
<td>...</td>
<td>( F_n )</td>
<td></td>
</tr>
</tbody>
</table>

In a cost benefit analysis the future net cash flows \( F_1, F_2, \ldots, F_n \) would be net benefits represented monetarily as positive net cash inflows. In a life cycle cost calculation they would be cash outflows representing future operating costs. In either case their total present value PV is given by

\[
PV = \frac{F_1}{1+k} + \frac{F_2}{(1+k)^2} + \ldots + \frac{F_n}{(1+k)^n}
\]
Note: If the cash flows are uniform i.e.:
\[ F_1 = F_2 = \ldots = F_n = F, \]

\[ PV = F(PVIFA_{kn}) \text{ where } PVIFA_{kn} = \left( \frac{1-(1+k)^{-n}}{k} \right) \]

The accept/reject decision for any investment that generates positive net cash inflows, is made by comparing the total present value of the future net cash flows, PV, with the initial investment, I. This is usually accomplished by calculating the net present value (NPV) where

\[ NPV = PV - I. \]

The NPV is the total net benefit yielded by the investment over its life, expressed in terms of money in hand right now. Acceptance of the investment requires that NPV ≥ 0.

An alternative method to NPV for comparing the present value of an investment's future cash flows (PV) to its initial outlay (I) is provided by the profitability index (PI), which is a benefit/cost ratio and is defined as PI = PV/I. Project acceptance requires that PI ≥ 1.

In a life cycle cost calculation all of the future cash flows represent costs and are therefore outflows, as is the initial investment. Total life cycle costs are calculated by summing the present value of the future cash outflows and the initial cost (PV + I). The sum PV + I represents the present value of the total costs of a project over its entire life.

**NPV - Example Problem & Solution (12.4a):**

A homeowner is contemplating replacing an existing electric baseboard heating system with an oil fired forced hot air system. The initial cost of installing the oil system would be $6000, comprised of $4000 for the ductwork and $300 for the oil tank and components and $1700 for the furnace. The furnace is expected to last 20 years. The cost of funds after adjustment for taxes and risk is 6.365 percent annually (see section 1.10). At current electricity rates the all electric system costs $2000 to operate per year. Given current oil prices the oil fired system's annual fuel costs would be $750. In addition, maintenance of the oil furnace would amount to $40 a year. Thus, the switch to oil would result in a savings of $1210 annually based on current fuel costs. However, given the rate at which electricity costs and oil prices are projected to increase, the homeowner anticipates that this
<table>
<thead>
<tr>
<th>YEAR</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASH FLOW</td>
<td>-6000</td>
<td>1259</td>
<td>1309</td>
<td>1362</td>
<td>1417</td>
<td>1473</td>
<td>1533</td>
<td>1594</td>
<td>1658</td>
<td>1725</td>
</tr>
<tr>
<td>PVIF_{0.365,n}</td>
<td>0.940</td>
<td>0.884</td>
<td>0.831</td>
<td>0.781</td>
<td>0.735</td>
<td>0.691</td>
<td>0.649</td>
<td>0.610</td>
<td>0.574</td>
<td></td>
</tr>
<tr>
<td>PV-CASH FLOW</td>
<td>1183</td>
<td>1157</td>
<td>1132</td>
<td>1107</td>
<td>1082</td>
<td>1058</td>
<td>1035</td>
<td>1012</td>
<td>990</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>YEAR</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
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<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
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<tbody>
<tr>
<td>CF</td>
<td>1794</td>
<td>1866</td>
<td>1941</td>
<td>2019</td>
<td>2100</td>
<td>2184</td>
<td>2271</td>
<td>2362</td>
<td>2457</td>
<td>2555</td>
<td>2657</td>
</tr>
<tr>
<td>PVIF</td>
<td>0.540</td>
<td>0.507</td>
<td>0.477</td>
<td>0.448</td>
<td>0.422</td>
<td>0.396</td>
<td>0.373</td>
<td>0.350</td>
<td>0.329</td>
<td>0.310</td>
<td>0.291</td>
</tr>
<tr>
<td>PV-CF</td>
<td>968</td>
<td>946</td>
<td>926</td>
<td>905</td>
<td>885</td>
<td>865</td>
<td>846</td>
<td>827</td>
<td>809</td>
<td>791</td>
<td>774</td>
</tr>
</tbody>
</table>

Savings will increase each year yielding the cash flow pattern over time (see sections 12.5-3 and 12.5-4) shown above.

To calculate the net present value (NPV) of this investment we first calculate PV, the sum of the present values of the future net cash flows, by multiplying each of the net cash flows given above for the years 1 through 20 by the corresponding value of PVIF_{0.345,n} = 1/(1.0636)^n to obtain the present values of the cash flows in each year shown above in the rows labeled "PV-CASH FLOW" and "PV-CF". These figures are summed over all years 1 through 20 to get PV = $19300. Finally, subtracting the initial investment of $6000 from PV gives NPV = $13300.

This investment is obviously well worth making. The present worth of the future cash inflows generated by the investment exceeds the present cost of making the investment by $13300.

**Additional Investment Criteria (12.5)**

The following five sections present and evaluate four additional criteria for making investment decisions which are alternatives to the net present value criterion. Each of these has advantages and/or disadvantages relative to the others and to NPV and each of them are used in practice. Except for the payback period, each takes account of the time value of money and generally results in the same accept/reject decision as NPV. The latter is always theoretically correct, however, and is the standard against which the others are compared. If only one criteria is used, it is typically NPV.

**Annual Worth or Cost (12.5-1)**

An investment's net annual benefit or worth can be determined by calculating \( AW = \frac{NPV}{(PVIFA_{\alpha,n})} \). The result, \( AW \), is the uniform annual cash flow whose total present value over the life of the investment is equal to the net present value. \( AW \) may be thought of as the average annual net benefit or excess return over cost of an investment taking account of the time value of money. Some decision makers find \( AW \) an easier concept to understand and appreciate than NPV.
In the problem presented in section 12.4a above NPV = $13300 and PVIFA_{k,20} = 11.13765. Therefore AW = $13300/11.13765 =$1194.

Life cycle costs can also be expressed on an annual basis by calculating AC = (PV + I)/(PVIFA_{k,n}). AC is the uniform annual cash flow whose present value is the same as the present value of the project's total life cycle costs. If the project results in a measurable annual output, Q, of a product or service, the "levelized" cost per unit is given by (AC)/Q.

Annualizing a project's net benefits or life cycle costs is particularly useful when a choice must be made between alternative investments that have different expected economic lives. In this circumstance, the alternative chosen should be that with the largest NPV, = AW/k or smallest AC/k.

**Internal Rate of Return (12.5-2)**

Another important criterion that can be used for an investment which yields positive net cash inflows (as in a cost/benefit analysis) is provided by the internal rate of return (IRR). The IRR is defined as the rate of interest which equates the present discounted value of the future net cash flows to an investment's initial cost or the investment's NPV (as defined in section 12.4) to zero.

For the investment opportunity described above in section 12.4, IRR is the value of r which satisfies

\[ I = \frac{F_1}{(1 + r)} + \frac{F_2}{(1 + r)^2} + \ldots + \frac{F_n}{(1 + r)^n} \]

This equation must be solved for r by trial and error.

If the cash flows are uniform the equation for IRR becomes

\[ I = F(PVIFA_{r,n}) \text{ where } PVIFA_{r,n} = \left( \frac{1-(1+r)^{-n}}{r} \right) \]

An investment is acceptable if IRR = r is greater than or equal to the cost of capital, k. The IRR is the rate of interest earned on the funds invested in the project and if the IRR exceeds the cost of those funds the investment is clearly acceptable. Many decision makers find a high IRR a more meaningful indicator of an investment's quality than a large NPV as the latter is a function of scale as well as profitability.
IRR - Example Problem & Solution ((12.5-2a):

To compute the IRR for the problem presented in section 12.4a the NPV must be calculated as shown in that section for alternative interest rates (values of \( r \) in the factor PVIF\(_{r,n}\)) until the value of \( r \) at which the NPV is zero is determined. That value of \( r \), the IRR, is 24.41%. To verify this result we multiply the cash flow for each year given in the table below by the value of the PVIF\(_{24.41\%,n}\) factor for that year to obtain the present value of the cash flow (shown in the rows labeled "PV-CASH FLOW" and "PV-CF") and sum over all years 1 through 20. The result is the total present value (PV) of the future cash flows generated by the investment in the new oil fired heating system and is equal to $6000. Subtracting the initial investment (I) of $6000 gives a NPV equal to zero.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>9</th>
</tr>
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<tbody>
<tr>
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<td>-6000</td>
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<td>1309</td>
<td>1362</td>
<td>1417</td>
<td>1473</td>
<td>1533</td>
<td>1594</td>
<td>1658</td>
<td>1725</td>
</tr>
<tr>
<td>PVIF(_{24.41%,n})</td>
<td>0.804</td>
<td>0.646</td>
<td>0.519</td>
<td>0.417</td>
<td>0.336</td>
<td>0.270</td>
<td>0.217</td>
<td>0.174</td>
<td>0.140</td>
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<tr>
<td>PV-CASH FLOW</td>
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<td>846</td>
<td>707</td>
<td>591</td>
<td>494</td>
<td>413</td>
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<th>17</th>
<th>18</th>
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</thead>
<tbody>
<tr>
<td>CF</td>
<td>1794</td>
<td>1866</td>
<td>1941</td>
<td>2019</td>
<td>2100</td>
<td>2184</td>
<td>2271</td>
<td>2362</td>
<td>2457</td>
<td>2555</td>
<td>2657</td>
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<tr>
<td>PVIF</td>
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<td>0.090</td>
<td>0.073</td>
<td>0.058</td>
<td>0.047</td>
<td>0.038</td>
<td>0.030</td>
<td>0.024</td>
<td>0.020</td>
<td>0.016</td>
<td>0.013</td>
</tr>
<tr>
<td>PV-CF</td>
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<td>141</td>
<td>118</td>
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<td>82</td>
<td>69</td>
<td>58</td>
<td>48</td>
<td>40</td>
<td>34</td>
</tr>
</tbody>
</table>

As the IRR of 24.41% greatly exceeds the cost of capital of 6.365%, this is an excellent investment, equivalent to lending money out at an annual compound rate of interest of 24.41% (provided, as noted below in section 12.5-4, the interest payments can be reinvested as they are received at an interest rate of 24.41%).

**Payback Period (12.5-3)**

An investment's payback period is the number of years required for the net annual cash flows to accumulate to an amount equal to the initial investment. Investment decisions should not be based on the payback period, as this criterion ignores the time value of money (the cost of capital and the timing of the cash flows during the payback period). It also ignores all cash flows received after the end of the payback period. It is defended by its dwindling number of advocates for its simplicity and as a means of taking account of the risk factor in investment decisions. However, superior means for handling risk exist and these are discussed below in section 12.10.
Comparison Between NPV and IRR (12.5-4)

If the net cash flows in each future period are all positive, the accept/reject decision given by NPV and IRR for a single investment considered in isolation (as opposed to a comparison between two mutually exclusive alternatives) will be the same. Unfortunately, if the net cash flows in one or more of the future periods reverse sign and become negative, then the two criteria can give different answers.

To determine the difference between NPV and IRR we must restate these criteria by multiplying

\[ NPV_k = \frac{F_1}{(1+k)} + \frac{F_2}{(1+k)^2} + \ldots + \frac{F_n}{(1+k)^n} - I \geq 0 \text{ by } (1+k)^n \]

and

\[ NPV_r = \frac{F_1}{(1+r)} + \frac{F_2}{(1+r)^2} + \ldots + \frac{F_n}{(1+r)^n} - I = 0 \text{ by } (1+r)^n \]

to get respectively

\[ NFV_k = F_1(1+k)^{n-1} + F_2(1+k)^{n-2} + \ldots + F_n - I(1+k)^{n} \geq 0 \]
\[ NFV_r = F_1(1+r)^{n-1} + F_2(1+r)^{n-2} + \ldots + F_n - I(1+r)^{n} = 0 \]

These restatements of the NPV and IRR criteria in terms of the project's net future value (at the end of its life) indicate that both assume that as each of the future cash flows \( F_1, F_2, \ldots, F_n \) are received they are reinvested. The difference between NPV and IRR is due to the difference in reinvestment rates for the cash flows, \( k \) vs \( r \), assumed by NPV and IRR, respectively.

The reinvestment rate of \( k \) assumed by NPV is realistic. It is always possible to reinvest the cash flows received each period at the rate \( k \), because \( k \) is defined as the rate at which funds have been borrowed or can be invested elsewhere. The same cannot be said for \( r \) which is whatever the IRR turns out to be. When \( r \) is very high relative to \( k \), the use of \( r \) as the reinvestment rate is particularly unrealistic and greatly inflates the IRR.
Modified Internal Rate of Return (12.5-5)

A superior measure of an investment's rate of return is provided by the modified internal rate of return (MIRR). To determine the MIRR, r is replaced by k as the reinvestment rate for the future net cash flows in the last equation given above for IRR. Therefore, MIRR is the value of r' which satisfies the equation

\[ NFV_{r'} = F_1(1+k)^{n-1} + F_2(1+k)^{n-2} + ... + F_n - I(1+r*)^n = 0 \]

or

\[ I = \left( \frac{F_1(1+k)^{n-1} + F_2(1+k)^{n-2} + ... + F_n}{(1+r*)^n} \right) / I \]

\[ r^* = \left( \frac{F_1(1+k)^{n-1} + F_2(1+k)^{n-2} + ... + F_n}{I} \right)^{1/n} - 1 \]

The MIRR and IRR may be interpreted as the annual compound rates at which the amount I would have to be invested elsewhere (i.e. in a financial security) in order to obtain as much money by the end of year n as will be obtained from an investment generating the future net cash flows F₁, F₂, ..., Fₙ assuming that these are reinvested as received at an annual compound rate of k (MIRR) or r (IRR).

MIRR- Example Problem & Solution (12.5-5a):

To calculate the MIRR for the problem presented above in section 12.4a the cash flow for any year t given in the table below is

<table>
<thead>
<tr>
<th>YEAR</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>-6000</td>
<td>1259</td>
<td>1309</td>
<td>1362</td>
<td>1417</td>
<td>1473</td>
<td>1533</td>
<td>1594</td>
<td>1658</td>
<td>1725</td>
</tr>
<tr>
<td>FVIF₆₃₆₅,₂₀₋ₜ</td>
<td>3.230</td>
<td>3.037</td>
<td>2.855</td>
<td>2.684</td>
<td>2.523</td>
<td>2.372</td>
<td>2.230</td>
<td>2.097</td>
<td>1.971</td>
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<tr>
<td>FV-CASH FLOW</td>
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<td>3888</td>
<td>3802</td>
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<td>3636</td>
<td>3556</td>
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<table>
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<th>12</th>
<th>13</th>
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<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>1794</td>
<td>1866</td>
<td>1941</td>
<td>2019</td>
<td>2100</td>
<td>2184</td>
<td>2271</td>
<td>2362</td>
<td>2457</td>
<td>2555</td>
<td>2657</td>
</tr>
<tr>
<td>FVIF</td>
<td>1.853</td>
<td>1.743</td>
<td>1.638</td>
<td>1.540</td>
<td>1.448</td>
<td>1.361</td>
<td>1.280</td>
<td>1.203</td>
<td>1.131</td>
<td>1.064</td>
<td>1.000</td>
</tr>
<tr>
<td>FV-CF</td>
<td>3325</td>
<td>3252</td>
<td>3180</td>
<td>3109</td>
<td>3040</td>
<td>2973</td>
<td>2907</td>
<td>2843</td>
<td>2780</td>
<td>2718</td>
<td>2657</td>
</tr>
</tbody>
</table>

multiplied by the value of the \( FVIF_{6.365,20-t} = (1.06365)^{20-t} \) factor given for year t to obtain the value of the cash flow at the end of year 20 assuming that it is reinvested for 20-t years at the cost of capital 6.365%. The resultant values of the cash flows at the end of the investment's life (shown in the rows labeled "FV-CASH FLOWS" and "FV-CF") are summed over all years 1 to 20 to obtain the total future value of the reinvested cash flows. That
sum is $66301. The MIRR is the interest rate which equates the present value of $66301 to the initial investment of $6000 and is determined by calculating $MIRR = (66301/6000)^{(1/20)} = 12.76\%$.

Determining the Interest Factors (12.6)

The values of the interest factors $PVIF_{k,n}$, $PVIFA_{k,n}$, and $FVIF_{k,n}$ used in the equations for NPV, IRR, and MIRR may be determined in a number of ways:

1) They may be calculated directly from the formulas for the interest factors given above.

2) They may be found in interest tables at the back of any text on financial management or engineering economy or in the CRC Handbook.

3) They may be computed using a financial calculator.

4) They may be determined from a spreadsheet program. In Lotus the function @PV(payment, interest, term) calculates the present value of an annuity (a sequence of uniform annual cash flows), @NPV(interest, range) determines the present value of series of non-uniform cash flows located in the given range, and @IRR(guess, range) calculates the internal rate of return on an investment whose cash flows (including the initial cost as a negative cash flow) are found in the given range. The function argument "guess" is an initial interest rate (expressed as a decimal fraction) used by the program to begin the iterations to solve for IRR.

Future Net Cash Flows (12.7)

All of the steps required to conduct a cost/benefit analysis or life cycle cost study have been outlined above except for two. The two remaining are, first, the estimation of a project's future net cash flows taking into account inflation and taxes where appropriate. The second is the determination of the cost of capital, $k$, taking into account inflation, taxes and, most importantly, risk.

The critical rule in estimating future cash flows is to include all incremental cash flows, both inflows and outflows, that are expected to occur as a result of the initial investment, except the interest payments on borrowed capital. The key consideration is the difference the investment makes. All changes in future cash flows that occur as a result of the investment must be identified. Interest payments are not treated as cash flows because their cost is included in the cost of capital, $k$, used to discount the future cash flows.
The procedure for calculating cash flows varies depending on whether or not the investment will produce taxable income or savings in the future.

When income taxes are involved, as in the case of a business investing in plant and equipment, \( F_t \), the net cash flow in any year \( t \) provided by a non-financial investment, is given by

\[
F_t = (S_t - O_t - D_t)(1-T) + D_t, \quad F_t = (S_t - O_t)(1-T) + TD_t, \text{ or } F_t = S_t - O_t - T(S_t - O_t - D_t)
\]

where

- \( S_t \) = Δ benefits (revenue or savings) generated in year \( t \)
- \( O_t \) = Δ out-of-pocket expenses in year \( t \)
- \( D_t \) = Δ depreciation expense in year \( t \)
- \( T \) = marginal income tax rate.

The first of these three alternative formulas for \( F_t \) states that the net cash flow is the incremental after tax income plus depreciation expense resulting from the investment. The second gives the cash flow as the incremental after tax gross profit before depreciation plus the tax shield of depreciation (the reduction in income tax liability due to the depreciation charge). The third definition simply states that the net cash flow is revenue minus cash expenses and income tax payments. All three definitions are mathematically identical.

When an individual, a non-profit institution or government agency invests in a physical asset, such as a new heating system or public facility, taxable income is typically not generated and the calculation of the future annual cash flows simplifies to just

\[
F_t = S_t - O_t.
\]

**Future Net Cash Flows and Inflation (12.8)**

The value of \( k \) used to discount future cash flows will normally be based on actual current long term market interest rates, sometimes called "nominal" rates. These rates include a component to cover expected inflation plus provide what is termed a real rate of return, over and above inflation. If \( k \) is based on these nominal rates, inflation must also be taken into account in forecasting future cash flows. What is required is a best estimate of the number of dollars actually expected to be received or spent in each future period. That estimate must reflect the expected impact of inflation on the projects' future benefits and costs.

If the effect of inflation is very uncertain, better estimates of future cash flows will usually be obtained by assuming growth of both benefits and costs at the general rate of inflation than by ignoring inflation altogether.
The increase in future cash flows due to inflation is often forecast by assuming that the cash flows grow at a constant annual compound rate, \(e\), frequently called the "escalation" rate. Future cash flows are equal to base year cash flows times \((1 + e)^n\) or \(FVIF_{e,n}\).

**Computing Future Cash Flows - Example Problem & Solution (12.8a):**

The table below illustrates the calculation of the future cash flows generated by an investment in an oil fired heating system as described above in section 12.4a. The oil system will replace electric heating currently costing \$2000\ a year. Given current oil prices the oil fired system's annual fuel costs would be \$750. In addition, maintenance of the oil furnace would amount to \$40\ annually. Electricity rates and oil prices are projected to increase at an annual compound rate of 0.2 and 0.5 percent respectively above the expected 4.0 percent rate of inflation. Maintenance costs will increase at the rate of inflation. Given the anticipated rate of increase in electricity rates the annual savings in any future year \(t\) from eliminating electric heating will be \$2000(1.042)^t\. Similarly, the fuel and maintenance costs of the oil system in year \(t\) are expected to be \$750(1.045)^t\ and \$40(1.04)^t\ respectively. These savings and costs for all years \(t = 1, 2, \ldots, 20\) are presented above in columns C, D, and E. The net cash flow in any year \(t\) is just the difference between the savings and costs i.e. \$2000(1.042)^t - \$750(1.045)^t - \$40(1.04)^t\, and is calculated by subtracting the figures in columns D and E from C. The net cash flows for all years \(t = 1, 2, \ldots, 20\) are presented above in column F. These are the cash flows used to compute NPV, IRR, and MIRR in sections 12.4a, 12.5-2a, and 12.5-5a above.

If instead of an individual homeowner, a corporation was considering converting from electric to oil heat, the calculation of the future cash flows would have to be modified as shown in the table below. In this illustration the corporation's marginal federal plus state income tax rate is assumed to be 40 percent. The depreciable basis of the oil heating system is \$6000\ and the MACRS depreciation percentages for 10 year life property will be used to calculate the annual depreciation charges. The electric baseboards are fully depreciated for tax purposes and have zero current market and future salvage values. All other facts about the conversion are assumed to be the same as given above.
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<tr>
<th>YEAR</th>
<th>INITIAL COST</th>
<th>ANNUAL SAVINGS</th>
<th>FUEL COST</th>
<th>MAINT. COST</th>
<th>NET SAVINGS</th>
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<td>$87.64</td>
<td>$2,657.48</td>
<td></td>
</tr>
</tbody>
</table>

The calculation of the future cash flows for this case begins with the net savings from conversion shown in column F above. These net savings must be multiplied by one minus the corporation's income tax rate (1-0.4) to put them on an after tax basis. The results are presented in column K below. To obtain the corporation's net cash flows from the oil system investment the tax savings from depreciation must be added to the after tax net savings given in column K. The depreciation tax savings are calculated by multiplying the $6000 initial cost of the system by the MACRS depreciation percentages given in column L and then by the corporation's income tax rate of 0.4. The resultant tax shield of depreciation is presented for each year in column M. Adding the depreciation tax shield to the after tax net savings for each year gives the net cash flows shown in column N.
Life Cycle Cost Calculations (12.8b):

The future operating costs of the electric and oil systems given above in columns C, D, and E of section 12.8a and in the same columns of the table below can be used along with the $6000 initial cost estimate for the oil system to compute the life cycle costs of these two alternatives. (Note that for electric heating we will be calculating just the incremental life cycle costs of retaining the system, -which is all that is relevant for decision making in any case.) The life cycle costs of the electric system may be calculated by multiplying the operating costs in each future year

<table>
<thead>
<tr>
<th>Column</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
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given above in column C by the value of the PVIF$^{6.365,n}$ factor given for that year in column B. The resulting present value operating costs are shown above in column F. Their sum for all years 1 to 20 -$32459- is the total cost of operating the electric system for 20
years expressed in terms of money in hand right now. To express the cost in terms of an equivalent uniform annual cash flow the $32459 total present cost must be divided by PVIFA\(_{6.365,20}\) = 11.1377 as explained in section 12.5. The result is $2914.

The life cycle costs of the oil heating system may be calculated similarly. The fuel and maintenance costs in each future year given below in columns D and E must be multiplied by the value of the PVIF\(_{6.365,n}\) factor given for that year in column B. The sum of those present costs for all years 1 to 20 (as shown in columns G and H respectively) must be added to the initial cost of $6000. The result -$19159- is the total cost of operating the oil heating system for 20 years expressed in terms of money in hand right now. The annualized cost is $19159/PVIFA\(_{6.365,20}\) = $19159/11.1377 = $1720.

<table>
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<tr>
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<th>FUEL COST</th>
<th>MAINT. COST</th>
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<td>D(12.8a)</td>
<td>E(12.8a)</td>
<td>(C*B)</td>
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<tr>
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<td>(D*B)</td>
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The difference between the total present costs of the electric and oil heating systems ($32459 - $19159 = $13300) is also the NPV of the investment in the oil system.

**NPV Given Real Cash Flows (12.9)**

If both benefits and costs are expected to grow due to inflation at the same rate, inflation may be taken into account by modifying the discount rate, $k$, while leaving the cash flows at their base year values.

Recall that the cash flow in year $t$ generated by an investment in year 0 is given by

$$F_t = (S_t - O_t)(1-T) + TD_t$$

where $S_t$, $O_t$, & $D_t$ are sales revenue, out of pocket expenses and depreciation in year $t$, respectively.

Assume that $S_t$ and $O_t$ increase with inflation at an annual compound rate $e$ such that

$$S_t = S_0(1+e)^t \text{ and } O_t = O_0(1+e)^t,$$

where $S_0$ and $O_0$ are the year 0 sales revenues and out-of-pocket expenses, respectively.

Therefore, $F_t = (S_0 - O_0)(1-T)(1+e)^t + TD_t$.

Where $k$ is the nominal interest rate,

$$NPV = \sum_{t=1}^{n} \frac{(S_0-O_0)(1-T)(1+e)^t}{(1+k)^t} + \sum_{t=1}^{n} \frac{TD_t}{(1+k)^t} - I$$

Note that

$$\frac{(1+e)^t}{(1+k)^t} = \left(\frac{1+k}{1+e}\right)^t = \left(\frac{1+e+k-e}{1+e}\right)^t = (1+k_R)^t \text{ where } k_R = \frac{k-e}{1+e}$$

Therefore,

$$NPV = (S_0 - O_0)(1-T)\left( \sum_{t=1}^{n} \frac{l}{(1+k_R)^t} \right) + \sum_{t=1}^{n} \frac{TD_t}{(1+k)^t} - I$$
\[ NPV = (S_0 - O_0)(1 - T) \left( \frac{1 - (1 + k_R)^n}{k_R} \right) + \sum_{t=1}^{n} \frac{TD_t}{(1 + k)^t} - I \]

If depreciation is straight line, \(D_t = D_0\) and

\[ NPV = (S_0 - O_0)(1 - T)(PVIFA_{k_R,n}) + TD_0(PVIFA_{K,n}) - I \]

\[ NPV = (S_0 - O_0)(1 - T) \left( \frac{1 - (1 + k_R)^n}{k_R} \right) + TD_0 \left( \frac{1 - (1 + k)^n}{k} \right) - I \]

**Determining the Cost of Capital (12.10)**

The cost of capital, \(k\), used to discount the future net cash flows in a cost/benefit or life cycle cost study is both the interest rate that must be paid to acquire funds (including equity) and the rate that could have been earned if these funds were invested externally, i.e., in stocks or bonds. Which of these measures is most appropriate to use depends on the circumstances. For a business, the cost of acquiring funds is frequently easiest to determine. For a non-profit institution, government agency or individual, the opportunity cost may be the most important measure. In either case, cost must be measured on a risk adjusted basis. In computing the cost of raising funds, account must be taken of the risk that will be borne by the equity financed portion. The latter is a positive function of the inherent overall risks of the project and the amount of leverage, that is the proportion of debt financing. If the opportunity cost approach is employed, the estimate of the required return, \(k\), must reflect the project riskiness relative to an investment in a stock or bond.

Market interest rates have traditionally been viewed as comprised of three components: a return to compensate for risk, a return to cover inflation, and a pure rate of time preference (i.e., a reward for waiting). But several studies of average market rates over long time periods have revealed that the last component has
been very small. Risk free investments have provided a return just a bit above the rate of inflation. For example, from 1926 to 1989 the returns on the most commonly cited example of a long term "risk free" investment, long term U.S. treasury bonds, averaged a real return (actual minus inflation) of 1.5 percent per annum. High grade corporate bonds averaged 2.3 percent. Only risky investments have earned significant real returns. The stock market returned nine percent real and small company stocks about 14.5 percent real during the same 60 year period. The stock market earned a premium over the long term risk free rate of 7.5 percent.

To determine an appropriate value of k for a project using the opportunity cost approach, the analyst must add the expected future rate of inflation to a risk premium calculated by comparing the riskiness of the project to the riskiness of investing in stocks and bonds.

On what does the riskiness of a project depend? Risk, in any situation, is a function of the range of possible outcomes. In a cost/benefit or life cycle cost study, risk arises primarily because the project's future cash flows are uncertain. An important measure of return on any investment with uncertain future cash flow is provided by the concept of expected value. The risk adjusted estimate of k should be compared to the project's expected IRR or MIRR (E(r)). The latter is each possible value of IRR or MIRR which may occur given the project's future cash flows multiplied by that value's probability of occurring and summed over all possible values of IRR or MIRR.

For an investment with any given expected rate of return the greater the range of possible outcomes, the greater the probability of very high and very low returns and the greater the risk. Investors require a risk premium to compensate for risk because the possibility of a very good rate of return does not fully compensate for an equally likely very poor rate of return. The greater the range of possible rates of return the greater the riskiness and the required risk premium.

Research has shown that for investors of normal preferences and investments with normally distributed returns the riskiness inherent in a single investment considered in isolation is directly proportional to the probability weighted variation, i.e., the standard deviation, $\sigma_r$, of possible returns.

However, an investment cannot be considered in isolation when assessing risk. It is important to recognize that all investors have "portfolios" of other investments to which the investment in the project will be added. The critical issue is the project's effect on the riskiness, i.e., standard deviation of returns on the portfolio. For example, if the project's returns are negatively correlated with the returns on the other investments, its inclusion in the portfolio will reduce the variation in the returns on the entire portfolio and hence, the investor's total risk.
In financial theory individuals are commonly assumed to possess not only portfolios but well diversified portfolios. When an individual invests in a project of his own or an institution or agency invests on behalf of the public or a business firm invests on behalf of its shareholders, the individual's share of this investment is assumed to be added to a well diversified portfolio whose expected return and standard deviation are close to the market, essentially, the stock market. The project's addition to this portfolio's standard deviation and therefore, risk relative to the risk on the market is a function of the project's beta (β). The latter is equal to the correlation between the returns on the project and the entire stock market, multiplied by the ratio of the standard deviation of the returns on the project over the standard deviation of returns on the market.

The project's beta coefficient measures the riskiness of the project relative to the market. Consequently, the appropriate risk premium on the project is equal to beta multiplied by the risk premium on the market. The latter is the difference between the return on the market and the long term risk free rate. As noted above, this difference averaged 7.5 percent over the last 60 years.

In summary, to develop an estimate of the current cost of capital or required return, k, the investor must add a risk premium to the current long term treasury bond rate. The required risk premium is equal to the market risk premium of 7.5 percent multiplied by the project's beta. If, for example, the project's returns were thought to be about as variable as the market, beta would depend simply on the correlation between the project and market returns. The maximum value of the latter is, of course, one. The actual value will be significantly less than one. If it is say 0.5, beta will be 0.5. The project's risk premium will be 0.5 x 7.5 = 3.75 percent and given the current T-bond rate of about 5.75 six percent, k will be 9.5 percent. (Note that if the homeowner has a mortgage costing more than 9.5 percent, the minimum required return on the investment is equal to the mortgage rate.)

The estimate of k obtained by this procedure is valid, as it stands, only for projects being undertaken by organizations that do not pay income taxes. Tax considerations are likely to affect k for both individual taxpayers and for profit businesses.

If an individual is considering an investment in a physical asset that will result in a reduction in after-tax living expenses, the fact that these savings will not be taxed, whereas the income earned from a financial investment would be, must be taken into account in calculating the required return, k. For example, consider the problem first presented in section 12.4a above: a homeowner investing in a new heating system that will reduce future heating costs. The income generated by this investment will be in the form of cash savings that are not taxed. The required return on this investment is equal to k as estimated
above, multiplied by one minus the homeowner's marginal federal plus state income tax rate, that is:

\[ k_{AT} = k_{BT} (1 - T_p) \]

where \( k_{AT} \) = the required return after tax
\( k_{BT} \) = the required return before tax
\( T_p \) = the marginal federal plus state personal income tax rate.

In the example cited above, \( k_{BT} \), the required return before tax is estimated to be 9.5 percent. If the homeowner's marginal income tax rate were 33 percent, the required return after tax would be:

\[ k_{AT} = 9.5(1-0.33) = 6.365 \text{ percent} \]

Earning 6.365 percent on the investment in the heating system would be equivalent to earning 9.5 percent on a stock market investment of equal risk.

**The estimate of \( k \) for a business**

When calculating \( k \) for a business, account must be taken of the likelihood that the firm's assets will be financed in part by debt whose interest expense is tax deductible. Moreover the project's beta and consequently the risk premium required on the stockholder's equity will be increased as a result of the use of leverage (debt financing).

Where \( k_{SP} \) = the return required on the stockholder's equity invested in the project
\( R_f \) = the risk free rate (20 year T bond rate)
\( (k_M - R_f) \) = the expected risk premium on the market
\( D \) = the market value of the firm's debt
\( S \) = the market value of the firm's stock
\( T \) = the firm's marginal tax rate-federal and state combined
\( b_p \) = the project's beta coefficient if it were financed entirely with equity

\[ k_{SP} = R_f + \beta_p (1 + \frac{D}{S} (1-T))(k_M - R_f) \]

Note that as explained above

\[ \beta_p = \rho_{PM} \left( \frac{\sigma_p}{\sigma_M} \right) \]

where \( \rho_{PM} \) = the correlation coefficient between the returns on the project and the stock market
\( \sigma_p \) = the standard deviation of returns on the project
\( \sigma_M \) = the standard deviation of returns on the market.
The ratio D/S is based on the firm's normal or target ratio of total debt to total shareholder's equity (market values) for the firm as a whole. The project's investment is assumed to be financed with the same ratio of debt to equity as the firms' other assets.

The total required return on the project, $k$ is a weighted average of the return required on the stockholder's equity and the interest rate paid on the firm's debt. Where the latter is $k_D$,

$$k = k_D (1 - T) \left( \frac{D}{D + S} \right) + k_{SP} \left( \frac{S}{D + S} \right)$$

Consider, for example, a firm financed equally by debt and equity (market values) with an effective federal plus state income tax rate of 40 percent and a interest rate on debt of 8.0 percent. Assuming a T-bond rate of 5.75, a market risk premium of 7.5 percent and a project beta of 0.5, as in the example above, $k_{SP} = 5.75 + 0.5(1 + 1(0.6))7.5 = 11.75$. Thus, the overall cost of capital $k = 8.0(1-0.4)(0.5) + 11.75(0.5) = 8.275$.

**INVESTMENT DECISIONS - LIFE CYCLE COSTING:**

**SAMPLE PROBLEMS (12.11)**

Complete solutions to three different versions of the problem used throughout this module are presented below. The versions differ only with respect to the identity of the investor. In the first version the investor is an individual homeowner. In the second the investor is a non-profit agency and in the third, a small corporation.

All solutions were prepared using the Lotus spreadsheet program. The spreadsheets are shown with the columns identified by letter and the rows by number. The formulas used to calculate the cash flows, interest factors, and investment criteria are included in the spreadsheets. The variables in these formulas are identified by their "cell", that is, column and row, locations.

The spreadsheet solutions are also presented in the Lotus worksheet file CBLCC.WK1 accompanying this module. Readers may copy this file on to their own disks and use it to conduct their own cost/benefit analyses. To do so, they should make a second copy of the file, changing the name and then enter the initial cost, future savings, future operating costs, and cost of capital data in the appropriate locations to insure that the figures for initial cost, future net cash flows, and cost of capital remain in their present locations (assuming that $n = \text{or } 20$). The figures
given in the spreadsheet for NPV, IRR, MIRR, etc. will automatically change to their new values.

VERSION 1: INDIVIDUAL HOMEOWNER

A homeowner is contemplating replacing an existing electric resistance baseboard heating system with an oil fired forced hot air system. At current electricity rates the all electric system costs $2000 to operate annually. Given current oil prices the oil fired system's annual fuel costs would be $750. In addition, maintenance of the oil furnace would amount to $40 annually. Electricity rates and oil prices are projected to increase at an annual compound rate of 0.2 and 0.5 percent above the expected 4.0 percent rate of inflation. Maintenance costs will increase at the rate of inflation. The initial cost of installing the oil system would be $6000, comprised of $4000 for the ductwork and $300 for the oil tank and components and $1700 for the furnace. The furnace is expected to last 20 years. The current 20 year T-bond rate is 5.75 percent. The variability of returns on the oil system investment are judged to be about equal to the variability of the returns on the stock market, but the correlation between these returns is considered to be only 0.5. The homeowner's marginal federal and state income tax rate is 33 percent.

VERSION 2: NON-PROFIT AGENCY

All facts are the same as in Version 1 above except that the investor is a non-profit agency or institution. Due to its tax status, the agency will have no tax savings on interest paid or tax liability on interest earned. Thus, the required rate of return, k, is before tax.

VERSION 3: TAXABLE BUSINESS

All facts are the same as in Version 1 except that the investor is a small corporation. Its marginal federal plus state income tax rate is assumed to be 40 percent. The depreciable basis of the oil heating system is $6000 and the MACRS depreciation percentages for a 10 year life property will be used to calculate the annual depreciation charges. The electric baseboards are fully depreciated for tax purposes and have zero current market and future salvage values. The firm is financed fifty percent by equity and fifty percent by debt with a before tax annual interest cost of 8.0 percent.
## SOLUTION - VERSION 1: INDIVIDUAL HOMEOWNER

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<td>PRESENT VALUE OF NET SAVINGS: PV = @NPV(F80/100, F56..F75) = $19,299.52</td>
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<td>NET PRESENT VALUE OF PROJECT: NPV = PV - INIT COST (F82-B55) = $13,299.52</td>
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<td>INTERNAL RATE OF RETURN: IRR[@IRR(0.3, F55..F75) * 100] = 24.40945280</td>
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<td>= [(F82 * (1.06365) ^ 20 / B55) ^ (1/20) - 1] * 100</td>
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<td>LIFE CYCLE COST - ELECTRIC HEAT = PV OF ELECTRICITY COST</td>
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<td>= @NPV(F80/100, C56..C75)</td>
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<td>ANNUAL COST OF OIL SYSTEM = LIFE CYCLE COST / PVIFA(k,n)</td>
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<td>ANNUAL COST - ELECTRIC HEAT = LIFE CYCLE COST / PVIFA(k,n)</td>
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<td>116</td>
<td>COST OF CAPITAL (K) = T-BOND RATE+BETA*MKT RISK PREM.</td>
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<td>118</td>
<td>T-BOND RATE = 5.75 PROJECT BETA = 0.5 MKT RISK PREM = 7.5</td>
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<td>120</td>
<td>K = (5.75+0.5*7.5) = 9.5</td>
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<td>PRESENT VALUE OF NET SAVING: PV=@NPV(D1I9/100,F56..F75) = $14,736.70</td>
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<td>NET PRESENT VALUE OF PROJECT: NPV=PV-INITCOST(F121-B55) = $8,736.70</td>
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<td>INTERNAL RATE OF RETURN: IRR[@IRR(0.3,F55..F75)*100] = 24.40945280</td>
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<td>MODIFIED IRR: MIRR = [(PV*(1.095)^20/INIT COST)^((1/20)-1)*100</td>
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<td>LIFE CYCLE COST OF OIL SYSTEM = PV OF FUEL &amp; MAINT. COST+INIT COST</td>
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<td>ANNUAL COST OF OIL SYSTEM = LIFE CYCLE COST/PVIFA(k,n)</td>
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<td>ANNUAL COST -ELECTRIC HEAT = LIFE CYCLE COST/PVIFA(k,n)</td>
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### SOLUTION - VERSION 3: CORPORATION

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**INVESTMENT CASH FLOW PATTERN**

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**Notes:**
- **Column I** represents the year.
- **Column J** shows the initial investment.
- **Column K** indicates the net cost adjusted by the MACRS depreciation percentage.
- **Column L** calculates the depreciation shield.
- **Column M** computes the net cash flow by applying the formula `L * 0.4` for years 1 to 19 and `L - M` for year 20.
- **Column N** presents the net cash flow in parentheses. Some years have negative cash flows, indicating cash outflows.
<table>
<thead>
<tr>
<th>Column</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
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<tr>
<td>77</td>
<td>COST OF CAPITAL(K) = (COST OF DEBT AT) * .5 + (REQ'D RTN ON STOCK) * .5</td>
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<td>78</td>
<td>REQ'D RTN ON STOCK = T-BOND RATE + BETA * (1 + DEBT/STK AT) * MKT RISK PREM.</td>
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<td>79</td>
<td>T-BOND RATE = 5.75  BETA = 0.5  D/S AT = 1 * 6  MKT RISK PREM = 7.5</td>
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<td>80</td>
<td>DEBT CST = 8.0  K = (8.0 * 0.6) * 0.5 + (5.75 + 0.5 * (1 + 0.6) * 7.5) * 0.5 = 8.275</td>
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<td>81</td>
<td>PRESENT VALUE OF NET SAVINGS: @NPV(N80/100, N56..N75) = $11,460.28</td>
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<td>82</td>
<td>NET PRESENT VALUE OF PROJECT: PV - INIT COST(N82-J55) = $5,460.28</td>
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<td>INTERNAL RATE OF RETURN: [@IRR(0.3, N55..N75) * 100] = 18.53007703</td>
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<td>84</td>
<td>MODIFIED IRR: MIRR = [(PV*(1.08275)^(1/20))/INIT COST - (1/20) - 1] * 100</td>
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<tr>
<td>85</td>
<td>= [(N82*(1+N80/100)^(1/20))/J55] - (1/20) - 1] * 100</td>
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<td>= 11.83568324</td>
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<td>87</td>
<td>LIFE CYCLE COST OF OIL SYSTEM = PV OF FUEL &amp; MAINT. COST AFTER TA</td>
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<td></td>
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<tr>
<td>88</td>
<td>- PV OF DEPRECIATION TAX SHIELD + INITIAL COST</td>
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<tr>
<td>89</td>
<td>= (@NPV(N80/100, D56..D75) + @NPV(N80/100, E56..E75)) * (1 - 0.4)</td>
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<td>90</td>
<td>= N80/100, M56..M75 + K55</td>
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<td>92</td>
<td>LIFE CYCLE COST - ELECTRIC HEAT = PV OF ELECTRICITY COST AFTER TAX</td>
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<td>93</td>
<td>= (@NPV(N80/100, C56..C75)) * (1 - 0.4)</td>
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<td>NPV OIL = LCC ELECTRICITY - LCC OIL</td>
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<td>= L100 - K96</td>
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<td>= $5,460.28</td>
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<tr>
<td>98</td>
<td>ANNUAL COST OF OIL SYSTEM = LIFE CYCLE COST / PVIFA(k, n)</td>
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<td>= K96 / (@PV(1, N80/100, 20))</td>
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<td>101</td>
<td>ANNUAL COST - ELECTRIC HEAT = LIFE CYCLE COST / PVIFA(k, n)</td>
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<td>102</td>
<td>= L100 / (@PV(1, N80/100, 20))</td>
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CHAPTER 13

REGRESSION ANALYSIS

Definition (13.1):

In economics, regression analysis is used to estimate quantitative functional relationships between dependent variables and one or more independent causal variables from actual data - experimental, time series, cross sectional - when the relationship among the variables is statistical in nature rather than exact. By a statistical relationship it is meant that the dependent variable's observed values are generated by a probability distribution that is a function of other causal variables.

The values of economic variables are determined by the behavior of people and hence these variables are stochastic. Empirical investigation of the relationships among them requires the tools of statistical inference, including regression analysis. This is true, whether the purpose is to forecast future sales or the performance of an economic system or to predict the impact of a new innovation or government regulation.

For example, an economist might wish to estimate the relationship between the quarterly sales of a product in a given geographical area and the total personal disposable income earned per quarter by all individuals living in that area.

If this relationship is assumed to be linear, the hypothesis is that

\[ Y = a + bx + u \]  \hspace{1cm} 13.1

where \( Y \) = expected quarterly sales, \( X \) = total income, and \( u \) = error term.

This relationship is represented graphically by the upward sloping line in Figure 13.1. The data that will be used to estimate the parameters of this relationship consists of paired observations of \( X \) and \( Y \): \( X_i \) and \( Y_i \) for \( n \) quarters \( i = 1, \ldots, n \) and are represented in Figure 13.1 below by the points plotted around the line.
The errors, \( u \), in equation 13.1 above consist of differences between the actual observed values of \( Y \) and the expected or average values of \( Y \) determined by the linear relationship with \( X \). They are represented graphically in Figure 13.1 by the vertical distances between each point (representing an \( X, Y \) observation) and the line (representing the relationship between \( X \) and the expected value of \( Y \)).

There are a number of reasons why these errors will arise:

a) Measurement: The sales figures may have been inaccurately recorded.

b) Causal factors left out of account: Sales may have been affected by changes in prices or other variables influencing consumer purchase decisions that have not been included in the hypothesized relationship.

c) Random behavior of people: People do not always behave the same way each time they confront the same circumstances.

d) Misspecification: The functional form of the relationship may have been incorrectly specified.

Least squares regression is a means of estimating the parameters of the equation hypothesizing \( Y \) as a function of \( X \). Graphically, it is a means of fitting a line to the scatter of paired observations of \( X \) and \( Y \) in Figure 13.1. It involves choosing \( \hat{\alpha} \) and \( \hat{b} \), estimators of the true parameters \( \alpha \) and \( \beta \), so as to minimize the sum of the squared differences between the actual values of \( Y \) and the estimate of \( Y \) given by the regression equation. These differences are the estimated values of the errors, \( e_i \) for \( i = 1 \ldots n \). The least squares estimators \( \hat{\alpha} \) and \( \hat{b} \) minimize
\[
\sum_{i=1}^{n} e_i \hspace{1em} \text{where} \hspace{1em} e_i = y_i - \hat{y}_i, \hspace{1em} \hat{y}_i = \hat{a} - \hat{b} x_i, \hspace{1em} \text{and}
\]
\[n = \text{the number of observations}.\]

Expressions for \(\hat{a}\) and \(\hat{b}\) can be derived by setting the first partial derivatives with respect to \(\hat{a}\) and \(\hat{b}\) of the sum of the squared estimated errors equal to zero and solving the two simultaneous equations that result, to get

\[
\hat{b} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}
\]

and

\[
\hat{a} = \bar{y} - \hat{b} \bar{x}
\]

where \(\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}\) and \(\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}\).

If the errors are random, independent with a zero mean, that is \(E(u) = 0\), the estimators, \(\hat{a}\) and \(\hat{b}\), of the parameters, \(a\) and \(b\), of the true relationship obtained through least squares regression are statistically best. They will be closer on average to the true parameters than any other unbiased estimators in general use, regardless of the number of observations.

In the example cited above there is a one way causal relationship between \(X\) and \(Y\). Income effects sales but not vice versa. Frequently in economics a two way causal relationship exists between variables, as is illustrated below in the chapter on Econometric Modeling. In that case the methods of simultaneous estimation described in that chapter are required to obtain unbiased parameter estimates.

**Multiple Regression (13.2):**

Where two or more independent variables affect the dependent variable, it is important to include them in the regression equation.

If the true relationship is
\[ Y_i = a + b_1 X_{i1} + b_2 X_{i2} + u_i \]

the regression equation is

\[ \hat{Y}_i = \hat{a} + \hat{b}_1 X_{i1} + \hat{b}_2 X_{i2} \]

The estimators \( \hat{a}, \hat{b}_1, \hat{b}_2 \) are chosen so as to minimize

\[ \sum_{i=1}^{n} e_i^2 = \sum [Y_i - (\hat{a} + \hat{b}_1 X_{i1} + \hat{b}_2 X_{i2})]^2 \]

The values of the estimators can be determined by setting

\[ \frac{\delta \sum_{i=1}^{n} e_i^2}{\delta \hat{a}} = 0, \quad \frac{\delta \sum_{i=1}^{n} e_i^2}{\delta \hat{b}_1} = 0, \quad \text{and} \quad \frac{\delta \sum_{i=1}^{n} e_i^2}{\delta \hat{b}_2} = 0 \]

and solving these equations to get three simultaneous "normal" equations that can in turn be solved to get \( \hat{a}, \hat{b}_1 \) & \( \hat{b}_2 \).

Note that \( \hat{b}_1 \) is the best estimate of the effect on \( Y \) of changes in \( X_1 \) when \( X_2 \) is constant, and \( \hat{b}_2 \) is the best estimate of the effect on \( Y \) of changes in \( X_2 \) when \( X_1 \) is constant.

All important causal variables must be included in the equation. If some are omitted and they are correlated with those included, the least squares estimators will be biased.
Test Statistics (13.3):

Although the least squares estimators of the true parameters of economic relationships are frequently "best" estimates they are not necessarily good estimates. Very often economic data is so heavily affected by errors and the modeling process so uncertain that the regression results cannot be relied upon. Thus it is imperative to have some means of appraising the accuracy and reliability of the least squares estimators. This function is performed by the regression test statistics. The following is a listing with brief descriptions of some of the more important of the test statistics.

1) The coefficient of determination \( R^2 \) measures "goodness of fit", the proportion of variance in \( Y \) that is explained by the regression equation.

\[
R^2 = \frac{\sum(\hat{Y}_i - \bar{Y})^2}{\sum(Y_i - \bar{Y})^2} = \frac{\text{THE EXPLAINED VARIATION IN } Y}{\text{THE TOTAL VARIATION IN } Y}.
\]

\[
ALSO, \ R^2 = 1 - \frac{\sum e_i^2}{\sum(Y_i - \bar{Y})^2}.
\]

\( R^2 \) is a measure of the overall explanatory power of the regression equation. It ranges in value from 0 to 1. Low values suggest the omission of important causal variables raising the possibility that the coefficients of the included variables may be biased.

2) The standard error of estimate, SEE =

\[
\hat{\sigma}_u = \sqrt{\frac{\sum e_i^2}{n-v-1}}
\]

SEE is the standard deviation of the errors, corrected for degrees of freedom, and is used to determine the probability of errors of any given size. Note that degrees of freedom = \( n - \# \text{ of variables(v)} - 1 \).
3) The standard errors of the regression coefficients \( \hat{a} \) and \( \hat{b} \) are written as \( \sigma_a \) and \( \sigma_b \) respectively, where

\[
\sigma_b = \sqrt{\frac{\hat{\sigma}_u^2}{\Sigma(X_i - \bar{X})^2}}
\]

The t statistic is used to determine the probability of obtaining the value of \( \hat{b} \) observed purely by chance when the true value of \( b \) is smaller than or equal to any given value \( b' \) (which may be set equal to zero) for degrees of freedom less than 30.

\[
\frac{\hat{b} - b'}{\sigma_b} \quad \frac{\hat{a} - a^*}{\sigma_a}
\]

The t statistic for \( \hat{b} \) is \( \sigma_b \) and for \( \hat{a} \) is \( \sigma_a \).

'Computer software for running regressions and computing the test statistics described above is widely available. The spreadsheet program Lotus 123 has this capability (select the command sequence Data, Regression) as do statistical packages such as Minitab, SSPX, TSP, and SAS. The last two have the extended capabilities discussed below in the section on Econometric Modeling.'
CHAPTER 14

ECONOMETRIC MODELING

Definition (14.1):

Econometrics has been variously defined as "the quantitative analysis of actual economic phenomena based on the concurrent development of theory and observation, related by appropriate methods of inference" - Samuelson, Koopmans and Stone, 1958 - "and as the art and science of using statistical methods for the measurement of economic relations" - Chow, 1983.

These definitions imply that econometrics and regression analysis, as described above in chapter 13, are closely related, and, indeed, least squares regression is a cornerstone of econometric techniques.

As the definitions above also suggest, however, econometrics is far broader than simply regression, encompassing all methods of statistical inference that can be employed to produce "quantitative economic statements that either explain the behavior of variables we have already seen or forecast (i.e., predict) behavior that we have not yet seen, or both" - Christ (1966). In defining their field, many econometricians would emphasize those techniques - typically extensions or adaptations of regression analysis - created to cope with the special problems that often arise in estimating economic relations. Those that particularly come to mind are techniques to measure and eliminate autocorrelation among residuals and to model lagged relationships among variables in regressions on time series data.

To many practitioners, however, the term "econometrics" when coupled with "modeling" tends to have an even more specialized meaning. It applies especially to the body of techniques utilized to estimate the parameters of economic systems.

An economic system typically consists of many interdependent variables and the relationships among them. In estimating the equations of such systems, econometricians frequently encounter an obstacle known as "the identification problem." The latter is most easily illustrated by reference to the process of determination of price and output in a market. In Figure 14.1 below price and output are shown being simultaneously determined by the intersection of a demand and a supply curve. To model this process the econometrician must develop a quantitative estimate of both the demand and supply functions. Typically the data used to estimate these functions are past observations of price and output determined by the points of intersection between the demand and supply curves. If, in the past, the supply curve has been shifting (due, say, to production cost changes) while the demand curve has
remained fixed, the resultant intersection points trace out the demand function, as shown in Figure 14.2. If the demand curve has shifted (due, say, to income changes) while the supply curve has remained fixed, the intersection points trace out the supply curve
(Figure 14.3). The most likely outcome is movement of both curves yielding a pattern of price, quantity intersection points (as shown in Figure 14.4) from which the econometrician will be unable, without further information, to distinguish the demand curve from the supply curve or estimate the parameters of either. This is the identification problem.

Methods of Simultaneous Estimation (14.2):

In the illustration discussed above price and output are determined by the solution of two simultaneous equations and price and output are said to be jointly determined. This is a very common occurrence in economics. Thus, the statistical methods required to estimate equations for jointly determined economic variables find frequent application. Student projects in which the need to estimate explanatory equations for economic variables arises, whether for forecasting, policy analysis or impact assessment - will generally require their use.

Several techniques have been developed for the estimation of the structural parameters of an a priori specified system of simultaneous stochastic equations. These include indirect least squares, two stage least squares, instrumental variables, three stage least squares, full information maximum likelihood, limited information maximum likelihood, etc. Of these, only indirect and two stage least squares will be discussed here.

To illustrate the use of these techniques assume that the objective is to develop a model to forecast the annual sales and output of new cars in the United States and that the hypothesized demand function is

\[ A = a + b_1 P + b_2 (\Delta Y) + b_3 Y + u_d \]

(where \( A \) = new car sales
\( P \) = new car prices
\( Y \) = total personal disposable income and
\( \Delta Y \) = change in income per capita)

Suppose further that car prices (\( P \)) are believed to depend linearly on auto sales (\( A \)) as well as an index of production input costs (\( C \)) and production capacity (\( K \)). Thus, a simultaneous two way relationship is assumed to exist between \( A \) and \( P \). These variables are determined simultaneously by the solution of the demand function given above and the price or supply equation:

\[ P = e + d_1 C + d_2 K + d_3 A + u_s. \]

Indirect least squares:
To develop an equation to forecast auto sales the analyst can estimate an equation for the **reduced form**, which is obtained by substituting the price equation for price in the demand function to get:

\[ \hat{A} = a + b_1(e + d_1 C + d_2 K + d_3 A) + b_2(\Delta Y) + b_3 Y \]

\[ = \frac{a + b_1 e}{1 - b_1 d_3} + \frac{b_1 d_1}{1 - b_1 d_3} C + \frac{b_1 d_2}{1 - b_1 d_3} K + \frac{b_2}{1 - b_1 d_3} (\Delta Y) + \frac{b_3}{1 - b_1 d_3} Y \]

If \( A \) is regressed on \( C, K, \Delta Y, \) and \( Y \) as described above under Multiple Regression (13.3), the result will be an equation with quantitative estimates of the parameters of the reduced form equation for \( A \) given above which could be used to forecast future auto sales; moreover, in some cases (though not in the present example) it may be possible to derive estimates of the parameters of the original structural equations from the reduced form coefficients.

**Two Stage Least Squares:**

An alternative is to employ two stage LS regression by first estimating an equation for \( P \) by regressing \( P \) on all of the independent variables in the demand function for \( A \), plus one or more other determinants of \( P \), in this case \( C \) and \( K \), that do not appear in the demand function. The result is the 1st stage regression equation:

\[ P = t + \beta_1 C + \beta_2 K + \beta_3 (\Delta Y) + \beta_4 Y \]

In the second stage \( A \) is regressed on \( Y, \Delta Y, \) and \( \hat{P} \), the estimate of \( P \) given by the first stage regression rather than the original observed values of \( P \), to get:

\[ \hat{A} = \hat{a} + \hat{b}_1 \hat{P} + \hat{b}_2 (\Delta Y) + \hat{b}_3 Y. \]

The regression coefficients obtained from this second stage regression are unbiased, consistent estimators of the parameters of the original demand function.
References for Econometrics (14.3)


CHAPTER 15

SYSTEM DYNAMICS

(Prepared by Prof. Michael J. Radzicki)

What is System Dynamics (15.1)?

System dynamics is a computer modeling technique that has its origins in control theory, cybernetics, organizational theory, behavioral psychology, economics, and digital computer simulation. It is used to build models of systems that are experiencing problems and/or exhibiting behaviors that are not well understood. The completed models are used as "laboratories" for testing policy changes aimed at improving system behavior.

One of the great strengths of the system dynamics method is its ability to span disciplinary boundaries. System dynamics modeling is problem-oriented. That is, problems are modeled, not systems. Any information that is thought to be relevant to the modeling problem at hand, therefore, regardless of academic discipline, can be (and is encouraged to be) formally incorporated into a system dynamics model. Technically speaking, the non-discipline-constrained nature of the mathematics of dynamics enables any relationship -- biological, physical, or social -- to be represented formally in a system dynamics model. It is not unusual, therefore, for system dynamics models to embody knowledge from both the natural and social sciences.

A system dynamics model can be thought of as a "computerized case study." Unlike a traditional case study, however, "what-if" scenarios can be tested on the model. The structure of a system dynamics model consists of an extremely "rich" collection of stock and flow structures embedded in an interacting web of feedback relationships. These stocks, flows, and feedback relationships map-out the actual structure of a system -- including any physical and biological flows, nonmeasured or nonmeasurable variables that are important to the problem being addressed, and actual (as opposed to idealized) human decision making structures.

Stock and Flows and Dynamic Behavior (15.2)

A fundamental idea in system dynamics modeling is the "principle of accumulation." This principle says that all dynamic behavior in the world occurs when flows are accumulated (integrated) in stocks. A stock can be thought of as a bathtub. A flow can be thought of as a pipe and faucet assembly (a time derivative) that either fills-up or drains the tub. Figure 15.1 below shows some examples of stock and flow structures.
Feedback (15.3)

In a system dynamics model, stock and flow structures are embedded in feedback loops. There are two kinds of feedback loops -- positive loops and negative loops. Positive loops generate self-reinforcing behavior and negative loops generate goal seeking behavior. An example of a positive loop is presented in Figure 15.2. Inspection of the figure reveals that as VHS VCRs become more prevalent, there is more demand for VHS format tapes, which feeds back to generate more demand for VHS VCRs.

An example of a negative feedback loop is presented in Figure 15.3. Inspection of the figure reveals that if the actual temperature in a room drops below the desired temperature, the operation of the furnace increases (i.e., the furnace turns on), and the actual temperature is brought back into line with its desired value (goal).

Reference Modes (15.4)

As mentioned above, system dynamics modeling is problem-based. Thus, a system dynamics model cannot be built until a definition of the problem to which it will be addressed is arrived at.

System dynamicists define their dynamical problems with "reference modes." Reference modes are time series graphs of important system variables that are behaving problematically or in a perplexing way. In additional to helping the modeler identify important variables, the specification of a system's reference modes helps the modeler identify the time scope of the study (e.g., years, months, weeks, minutes; beginning in 1900, 1980, the first month of 1992, etc.), and the relevant behavior the model is supposed to mimic (e.g., oscillation, overshoot and collapse, sigmoidal growth.) Replication of a system's reference modes is one way that a system dynamicist builds confidence in a model. Finding policies that alter a system's problematic reference modes is the usual goal of a system dynamics study.

Sustainable Development from the System Dynamics Point of View (15.5)

A well-known concept in development and environmental economics is "sustainable development." This concept can be represented in a precise manner with system dynamics.

In terms of a stock and flow structure, sustainability occurs when the inflows to a stock exactly match the outflows from the stock. In Figure 1 for example, the stock of people (population) will remain stable if the sum of the two inflows, births and immigration, is exactly balanced by the sum of the two outflows, deaths and outmigration. Similarly, the stock of trees will
remain constant (and sustainable) as long as the harvest rate does not exceed the planting rate.

Note that the idea of sustainability does not necessarily imply a diminished use of a nation's resources. What it does imply is that the rate of resource use cannot exceed that rate of resource replenishment. In other words, if resource replenishment is high, resource use can be high. The higher the planting rate, the higher the sustainable rate of harvesting that is possible.

Steps an IQP Team would Follow to Produce a System Dynamics Study (15.6)

In order to produce a system dynamics study an IQP team would have to pursue the following steps:

1. **Identify the reference modes associated with the problem to be studied.** This means obtaining measured numerical time series data when available, and constructing time series graphs based on written information and detailed interviews (mental information) when numerical information is not available. Figure 15.4 is the characterization of information types put forth by Jay W. Forrester, the inventor of system dynamics. The point of the figure is that, by far, the most prevalent and important form of information is mental information. The amount and importance of available written and numerical information is less by several factors. Obtaining mental information by being "on-site" and talking to people intimately acquainted with the problem under study is thus the most important source of input into a system dynamics model.

2. **Identify the relevant stocks and flows.**
3. **Identify the relevant feedback loops.**
4. **Create a first cut of the model.** See if its variables replicate the reference modes.
5. **Iterate through steps 1-4.** Modeling is an iterative process!
Figure 15.1
Example of a Positive Feedback Loop

Figure 15.2

Example of a Negative Feedback Loop

Figure 15.3
Forrester's Characterization of Information

Figure 15.4