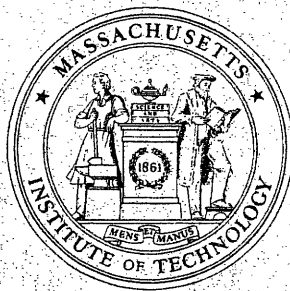


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Thoughts on Curriculum Development for
Public Systems Analysis

by
Joseph Ferreira, Jr.*
and
Ralph L. Keeney**

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*Assistant Professor of Operations Research and Urban Studies

**Assistant Professor of Civil Engineering

THOUGHTS ON CURRICULUM DEVELOPMENT FOR PUBLIC SYSTEMS ANALYSIS

Joseph Ferreira, Jr., and Ralph L. Keeney

Operations Research Center
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

ABSTRACT

Student interest in public sector problems has increased markedly in recent years. At M.I.T., this change has increased the demand for courses and programs of study that lead to the development of technologically advanced hardware such as pollution controlling devices. At the same time, it has promoted interest in analogous "software" problems associated with the formulation of public policy and the efficient operation of public systems. In this paper, we discuss curricula dealing with the more quantitative aspects of public systems analyses and describe a graduate subject which has been helpful in introducing students to the use of systematic analyses in addressing such problems.

1. CURRICULUM IN PUBLIC SYSTEMS ANALYSIS

Our interpretation of "public systems analysis" is broad, but it does not include all aspects of typical curricula in political science, sociology, urban studies and planning or public administration. We are concerned with formulating and solving public sector problems using approaches associated with management scientists, operations researchers and systems analysts.

By the term "public system", we mean any activities and operations dealing with topics which are the prime responsibility of some branch of federal, state or local government. For example, courts, fire departments, emergency health services, rent control and aspects of railroad operations are included in our definition. In this paper, "analysis" refers to a variety of systematic approaches useful for studying public systems. Most of the approaches we consider are quantitative in nature. However, we would include systematic procedures for generating objectives of a problem as well as a mathematical programming approach toward selecting an optimal solution from a set of feasible alternatives. One might categorize students interested in public systems analysis into three general types. First, there are students whose primary interest is public systems analysis. Their objective is to become specialists in the field. Second, there are students primarily interested in quantitative approaches toward problem solving but not necessarily in the area of public systems. The third group consists of students whose main interest is not in public systems analysis; they include undergraduates

surveying various areas and students in related fields such as public administration, urban studies and planning, engineering, economics, and political science. All three types might profit from an introductory course intended to develop the student's perspective on the use and limitations of various quantitative approaches toward studying public systems problems. However, the varying backgrounds and curricula for the students makes it difficult for any one course to be a suitable introduction for all three types.

Elsewhere, Alvin W. Drake has described some of his experiences and recommendations concerning courses in quantitative methods which are oriented toward the third type of student (Chapter 6, Ref. 1). Such a course would explore the types, uses and limitations of analytical techniques that have proved helpful in analyzing public systems. It would not be appropriate for students already well prepared in the areas of mathematical modeling, optimization techniques or probability theory.

Another type of introductory course is an applications oriented one which surveys the systems work which has been done on public sector problems. Such a subject has many advantages as a beginning subject on public systems analysis. It serves a wide spectrum of students highly motivated to start work immediately on "socially relevant" problems. The course indicates the need--and subsequently generates the student's interest--in taking additional subjects focusing on those analytical techniques which are useful for such work. In addition, the stress on applications helps many graduate students find thesis topics on public systems problems. This, in turn, contributes toward developing a school's research component in the area of public systems. Partly because most of the analytical work on public systems has occurred recently, many useful contributions have not required sophisticated mathematical models. Thus, the analytical background needed to follow much of what has been done is not extensive.

During the past few years, we have developed a one-semester subject that focuses on quantitative analyses of public systems problems. The next section describes this subject and discusses some of our experiences. Section 3 considers how this course has related to various educational programs at M.I.T. We conclude with a few comments on the development of similar subjects.

2. AN APPLICATIONS-ORIENTED SUBJECT ON PUBLIC SYSTEMS

Currently, the course Analysis of Public Systems is given jointly by the Department of Civil Engineering and the Department of Urban Studies and Planning at M.I.T. The main objective of the subject is to provide a comprehensive introduction to the area of public systems analysis. First of all, we want to give a good overall survey of the state of the art. This includes a coverage of the types of problems addressed and the types of techniques that have proven useful for certain problems. Second, we want the students to develop an ability to critically appraise systematic studies of public systems. Hopefully they will be able to read future studies and decide if they have any relevance to the real problem addressed.

For some students, this subject might be their only formal education in public systems analysis. For others, it is just the beginning. For this latter type of student, we hope to generate ideas and motivation for thesis research on particular public systems. In a few years, it may be the work of these same people that is most interesting and appropriate to discuss in a subject like ours.

2.1 ORIGIN OF SUBJECT: As was the case at many institutions in the mid 1960's, many engineers and scientists at M.I.T. turned their attention toward public systems problems. Two such individuals were Professors Alvin W. Drake and Philip M. Morse at the Operations Research Center. They developed and offered a special summer program entitled "Operations Research for Public Systems" each summer from 1966 to 1970. An account of the first year presentations is found in Morse (Ref. 3). During that same period, they and others at M.I.T. interested many students in doing research and applying analysis to public systems. Fortunately, we were two of these students.

In July 1969, just after the second author joined the faculty of the Department of Civil Engineering, we suggested an outline of a public systems course to Prof. Charles L. Miller, then department head. With Prof. Miller's support, development of the subject began. In the Fall of 1969, it was offered for the first time as a "special studies subject." The next Fall, it was a regular graduate subject of the Department of Civil Engineering with the name Analysis of Public Systems.

In September 1971, the first author joined the faculty of the Department of Urban Studies and Planning, and the two of us collaborated over the summer and gave a revised version of Analysis of Public Systems during the Fall of 1971. It is currently a regular graduate subject in each of our departments, and we plan to offer it once a year.

2.2 ORGANIZATION AND CONTENT: Analysis of Public Systems is described in the M.I.T. Catalog as follows:

Discussion and critical survey of applications of quantitative methods of analysis in the public domain. A problem-oriented course with emphasis on problem formulation, systematic analysis and the development of an ability to appraise public system studies. Typical topics include air and water quality control, fire department operations, the criminal justice system, housing, health, transportation facilities, and automobile accidents. The course will include seminar presentations by Institute faculty and invited guests with experience in public systems and will require a term project that critically summarizes the relevant work in a public systems area in which the student chooses to concentrate. Additional requirement: a written proposal to study a particular problem in that area which may initiate thesis research in subsequent terms.

Classroom Presentation. The subject meets for one and one half hours twice a week during the thirteen weeks of the Fall semester. For the first class during each of seven weeks, students were required to read a specified research paper and submit a short critical appraisal of the work. The class time was then spent discussing each article in depth to see exactly what was done, what assumptions were made, and whether the assumptions were reasonable and the results relevant to the problem addressed. The written appraisal assured us that most people had read, understood, and thought about the article. It also served to develop one's ability to place specific public systems efforts in a proper perspective. For the second session in each of the seven weeks, we tried to have an "expert" critique the specific paper and discuss current work in the area.

To be more precise, let us list the seven papers reviewed during the Fall of 1971 and briefly remark about each.

1. "A Rational Approach for Government Decisions Concerning Air Pollution" by Howard Ellis and Ralph L. Keeney, Chapter 19, (Ref. 1).
2. "Models of a Total Criminal Justice System" by Alfred Blumstein and Richard Larson, Operations Research, Vol. 17, pp. 199-232 (1969).
3. "Systems Analysis for Optimal Water Quality Management" by Ethan T. Smith and Alvin R. Morris, Journal of the Water Pollution Control Federation, Vol. 41, pp. 1635-1646 (1969).
4. "The Landing Capacity of a Runway" by Alfred Blumstein, Operations Research, Vol. 7, pp. 757-763 (1959).
5. "Simulation and Cost-Effectiveness Analysis of New York's Emergency Ambulance Service" by E. S. Savas, Management Science, Vol. 15, pp. B-608-B-627 (1969).

6. "Driver Accident Models and Their Use in Policy Evaluation" by Joseph Ferreira, Jr., Chapter 15, (Ref. 1).
7. "A Model of the Incidence of Venereal Disease in a Population of Associated Individuals" by Edward A. Silver, IEEE Systems Science and Cybernetics Conference, October, 1968.

This year, xeroxed copies of the papers were distributed to students. A book (Ref. 1) to be published by the M.I.T. Press in the Summer of 1972 includes most of them and will be used as the text for the course in subsequent years.

Papers 1, 6 and 7 were discussed in depth by ourselves. The class discussions of papers 2 through 5 were followed by guest lecturers. The paper by Blumstein and Larson developed models for use in manpower planning and resource allocation in the criminal justice system. Richard Larson of M.I.T. described to the class how this research originated and discussed a time shared interactive computer system which he and Alfred Blumstein have used to illustrate the uses of the models to criminal justice administrators (Chapter 16, Ref. 1).

The paper by Morris and Smith summarized work by the Delaware River Basin Control Authority to improve the water quality of the Delaware River. David Marks of M.I.T. was project engineer for the study. He spoke candidly about the origin, contribution, impact and shortcomings of the effort.

Alfred Blumstein's paper on runway capacity illustrated the value of a simple and resourceful analysis in lending insight into a complex system. Amedeo Odoni of M.I.T. has further developed Blumstein's models. He discussed these extensions and surveyed other areas of air traffic control where analyses have proved useful.

Emanuel Savas' article studied the ambulance service associated with a large metropolitan area hospital using a simulation model. Keith Stevenson of M.I.T. and the New York City-Rand Institute contrasted this work with his analytical studies of the allocation and effective use of emergency ambulance service (Chapter 8, Ref. 1).

The particular seven papers were chosen to cover a variety of areas and involve a variety of techniques useful for analyses. Some were to consider large problems--criminal justice system--and others, smaller ones--runway operations. The spectrum ranged from rather complete studies of well-defined, specific problems--ambulance service--to first-cut formulations of rather ill-defined problem areas--venereal disease. The papers included studies important to federal, state, regional, and local authorities. Finally, our topics were partially chosen because we had knowledgeable individuals willing and able to speak authoritatively on these subjects.

The six weeks of class not concerned with the

seven papers are utilized for two purposes. First, many examples of public systems analysis in areas other than those mentioned are summarized for the class. Areas discussed include housing, fire department operations, transportation systems, and health. Students are not required to do any preparing for these lectures, as it is felt their time could be better spent preparing a written report in their area of concentration. The last two weeks of class consist of student presentations surveying the work they have read in their respective areas. Subject Requirements. The major requirement of each student is a written report which surveys and appraises the systems work in a problem area in which the student chooses to concentrate. By researching an area more deeply than do any of the classroom discussions, the student gains a better perspective on the role of analysis in public systems and gets a thorough introduction into a problem area in which he or she may wish to continue studying during subsequent terms. We suggest topics for consideration, but the students must decide and write a short paper describing their proposed area by the fifth week of the term. They also must include a list of relevant sources of information. This requirement forces students to think of their area at an early date. It also allows us to suggest useful references and to warn students who choose areas that we feel are too broad to survey in one term.

Having chosen an area, the student must write three related papers, all due near the end of the term: the survey paper covering systems work in the area, an annotated bibliography of his readings, and a proposal to do a systematic study of a particular problem that the student feels is important.

The main paper is the survey. A general format which we suggest includes a statement of the problem area and a description of the current state of affairs, a detailed summary and critical appraisal of the systems work in the area, and a discussion of particular problems which seem suitable for quantitative analysis. Besides familiarizing the student with what has been done in his area, this exercise helps develop an ability to appraise the quality of quantitative work on public problems. These two characteristics together with the classroom discussions serve much of the objective of the subject for those students who plan no further study of public systems analysis. The survey paper also prepares students who wish to continue. Specifically, it serves as a very good background for one beginning or contemplating thesis research in his area of concentration.

The annotated bibliography should be written throughout the term as the student reads relevant literature. This helps the student force himself to appraise the work he reads, serves as a catalog of his reading that is useful when writing the survey

paper, and is a primary indicator to the individual of his own effort over the term. The annotated bibliographies are also very useful for other people interested in beginning work in an area. They serve as effective and efficient means to survey quickly the work that has been done.

The proposal to study a particular problem is intended to stimulate the student to think hard about the limitations and potential contributions of systematic analyses. He must seriously address the questions "What contribution can I make to which important problem? How should I go about it? How long will it take and how expensive might such a study be?" Our feeling is that one can inadvertently avoid hard thinking about these critical problems in doing the other assignments. To do a good job on the proposal, one cannot avoid these questions. The intent is that the proposals be from five to ten pages long, and if the student wishes, the same report may be used as an actual thesis proposal.

As previously mentioned, the last two weeks of the term are reserved for student presentations. Some choose to stress their survey, others their proposal. In all cases, the general feeling is that the presentations are interesting and instructive.

The areas of concentration selected by the students have covered a wide range of problems. The following list of paper titles indicates the broad range of areas studied.

- Report on Rat Control
- Measuring Economic Effects of River Planning
- The Future of Blood Banking Systems
- Safety Models for Air Traffic Control
- Locational Analysis as an Aid to Health Facility Planning
- Survey of Systems Work Relating to Food Distribution Policy in Periods of Severe Shortage
- Nuclear Power Research and Development: Perspective and Prospectus
- Operations Research Techniques as Applied to the United States Space Program
- Railroad Abandonments and Discontinuances
- The Problems of Household Waste Generation and Assembly
- The Effects of Legalizing Victimless Crimes
- Future Research in Welfare Systems
- Educational Planning for National Goals
- The Airport Access Problem

Several students have generated thesis topics in their area of concentration.

2.3 OUR EXPERIENCES: A typical class has 20-25 students--eighty percent graduate and twenty percent seniors. They represent various backgrounds: several branches of engineering, economics, management, political science, and urban studies.

Since many of the ideas and models discussed in the subject explicitly consider uncertainty, we list as a prerequisite some knowledge of the funda-

mentals of probability. The more quantitatively oriented students had taken a course in probability theory. Many of the others had not; however, we have waived this requirement where the student made a commitment to try to understand the probabilistic concepts as they arose. Brief tutorials on the mathematical aspects of several papers were given to appropriate students. Interestingly enough, the survey papers and individual critiques of this group were on a par with the rest of the class. The more quantitatively oriented students seemed to benefit from the class discussion of questions raised by those students from very different backgrounds.

Major problems which we have encountered are usually related to the difficulty in choosing an area of concentration. The term is rather short and individuals must decide on their area in approximately five weeks from the beginning to allow enough time to finish. Sometimes this has not been possible, and for those students much of the potential value of the course is lost.

Developing the student's ability to appraise public systems work has also been difficult. It is not too hard to comment critically on what was purported to be done--i. e., on explicit assumptions and results. The difficulty is commenting on what was not done: Was the problem even a reasonable one to consider? Is the approach valid? By commenting on each student's critiques of the seven discussion papers read during the term, we have attempted to help the student develop this ability.

In almost all of the class meetings, both of us are present, even though only one of us lectures. With the extra person, it is much easier to involve the class in a discussion about the topic being considered. Since we often have different perspectives, there is no problem identifying at least two points of view.

3. RELATIONSHIP TO OTHER M. I. T. SUBJECTS

One can roughly categorize subjects that focus on public systems into four general types: applications oriented survey courses; case study courses (which go into more depth); project courses which take a public domain problem and use systems techniques to try to "solve" it; and subjects which discuss the techniques generally found useful in analyzing public systems. Clearly there is overlap and our categorization is not precise or unique; however, the distinctions will facilitate our discussion of related courses at M. I. T.

On the basis of this division, we would classify Analysis of Public Systems as an applications oriented survey course. An example of a related case studies course at M. I. T. is Studies in Public Operations Management taught at the School of Management by Paul Kleindorfer. The course examines the application of Planning-Programming-

Budgeting Systems and systems analysis to the management of public operations.

There are many subjects which cover analytical techniques such as mathematical programming, probability, statistics, and decision analysis. Currently, one such subject which focuses on public systems problems is Analysis of Urban Service Systems taught by Aaron Fleisher, Richard Larson and Amedeo Odoni (Ref. 2). The course focuses on quantitative techniques useful in the analysis of large scale urban service systems such as fire and police departments, airports, and mass transit systems.

Several organized project courses focus on different public domain problems such as transportation, housing, or environmental quality. Those students who wish to pursue individual study on any public system have the option of doing thesis work in the area. Many students are now involved in such research.

Let us relate these subjects to two of the educational programs in public systems analysis with which we are most familiar. One can emphasize public systems while getting a master's degree in either Operations Research or Civil Engineering. Although the suggested subjects vary somewhat, both basically require approximately three courses in quantitative techniques (e. g., probability theory and mathematical optimization) two of the three specific public systems subjects described above, one or two subjects of the individual's choice, and a master's thesis in the public systems area.

Alternatively, master's degree programs such as that in M.I.T.'s Department of Urban Studies and Planning permit a student whose primary interest is not in quantitative aspects of public systems to take several courses in this area. A three-course sequence that has been well received by first-year graduate students is Analysis of Public Systems together with a technique oriented course such as Decision Theory and Policy Analysis in the Fall term, followed by Analysis of Urban Service Systems in the Spring.

At the doctorate level, the primary element which designates a public systems student is his dissertation. Many combinations of courses related to public systems analysis are possible within the framework of several departments' doctoral programs. For a doctoral student, the main value of a course like Analysis of Public Systems is that it helps the student to identify an interest in public systems analysis, select a thesis area, and begin research early in his graduate program.

4. COMMENTS ON THE DEVELOPMENT OF SIMILAR SUBJECTS

Our experiences indicate some considerations for developing subjects similar to Analysis of Public Systems. First, because of the tendency to let

things slide, the subject should have incentives for choosing an area of concentration early. We have chosen the proposal due in the fifth week plus the annotated bibliography as means to avoid slow starting. Of course, there is always the negative incentives of a poor grade, but unfortunately it is easy for the student not to realize the problem until it is too late.

Second, it is important to require everybody to read some papers prior to class. The discussion is then more meaningful and can begin to illustrate how to appraise such work. Earlier versions of this subject did not require this, and often class discussion would consider only what was done, as opposed to why it was done and was it any good. The specific papers chosen should reflect the availability of people knowledgeable on the subject (preferably the original authors) to speak to the class. Questions invariably are raised which can be adequately answered only by those who were directly involved in the work. Such sessions have proven to be very interesting to all present.

Finally, as we have mentioned, the use of two faculty teaching the subject has been a big plus. In classes where discussion of ideas--as opposed to more direct lecturing--plays an important role, two instructors can keep an interesting discussion going much more easily than one.

ACKNOWLEDGMENTS

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