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Law, Operations Research, and the Environment

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ABSTRACT

This paper discusses the legal component of a systems approach to environmental problems. In Part I, the scope and nature of the legal process is reviewed for the nonattorney reader. Aspects of the legal process that have a major impact on environmental areas are considered in more detail. In Part II, a systems approach integrating legal and technical solutions to environmental problems by operational research techniques is outlined.

Introduction

An initial attempt has been made to formulate a general legal-technical systems solution to environmental problems. Because the paper bridges several disciplines, summaries of each of the disciplines have been included. Part I, on the legal process, is intended as a survey of the relevant features of environmental law for the nonattorney reader. Part II includes surveys of the major techniques of operations research and system analysis for the reader not familiar with these developments. They are only surveys and as such lose the validity of more rigorous expositions.

In each instance the material is selected with a prior expectation that it interacts well with the other discipline. The reader familiar with operations research will, as he reads Part I, see suggestions of several operations research techniques that have been used for centuries by the legal profession—although not as part of a mathematical formulation. Likewise,

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the attorney reader will, when reading Part II, see balancing the equities in tradeoff and optimization studies, and courtroom strategy in game theory.

Part I. THE LEGAL PROCESS AND ENVIRONMENTAL LAW

This section consists of a review of the scope and nature of the legal process in preparation for the remainder of the paper. To investigate the legal process we might profitably investigate the educational process by which a person becomes familiar with the law and its daily implementation.

The list in Table 1 is typical of the legal topics that make up an average law school curriculum. An estimate of the topics most relevant to the solution of environmental problems is shown in the last column. An assessment of the nature of the topics listed in Table 1 is next made.

Substantive Law

Contracts, torts, property, and remedies constitute the basic substantive areas of law. Here, *substantive* is used to distinguish from *procedural.* It does not imply "of more importance."

The law of contracts concerns agreements between two or more people (or organizations) to do or not to do a particular thing. Once an express or implied agreement is reached, obligations normally ensue flowing from each party to the other. Failure to meet an obligation may result in damages to the aggrieved party. The law of torts imposes obligations on persons as a matter of social policy. As with contracts, failure to meet an obligation may result in damages.

The word *tort* is a term applied to a miscellaneous and more or less unconnected group of civil wrongs, other than breach of contract, for which a court may afford a remedy in the form of an action for damages or other relief.[1] Which civil wrong will be classified as a tort for which damages may ensue is a matter of custom, previous legal precedent, and statutory law. Included as torts are assault, trespass, nuisance, negligence, defamation, misrepresentation, and several types of interference.

The degree of severity of a tort and the nature of the liability of a tort feasor is, again, a matter of custom, legal precedent, and statute. The severity of a tort ranges from intentional behavior (all crimes against the person are also torts), to willful and reckless conduct, and to negligence.

Negligence is further delineated as ordinary negligence (failure to act as a prudent person–here the plaintiff must prove negligence), negligence

under the heading of *res ipsa loquitor* ("the thing speaks for itself"–here the defendant must prove he was not negligent), and negligence, *per se* (if the act was committed it is defined to be negligence by a specific statute). Certain types of conduct result in strict liability for which the concept of negligence or fault does not even enter. These types of conduct have been held to include keeping dangerous animals, the use of explosives and, generally, any "ultrahazardous activity."

The substantive law of torts plays a major role in the solution of environmental problems by legal process. The law of contracts does not. Neither does the law of property–except perhaps in the use of property,

Table 1. Typical Law School Curriculum

General nature of course	*Course*	*Most relevant to environmental solutions*
Introduction	Legal methods	
	Bibliography	
Basic substantive law courses	Contracts	
	Torts	Yes
	Property	
	Remedies	Yes
General law	Criminal law	
	Domestic relations	
	Wills	
	Trusts	
	Municipal law	Yes
Business law	Accounting	
	Taxation	
	Negotiable instruments	
	Business associations	Yes
Procedure	Code pleading	Yes
	Trial practice	
	Evidence	Yes
	Creditors' rights	
	Conflict of laws	
Origin of laws	Administrative law	Yes
	Legislative procedure	Yes
	Constitutional law	
Law practice	Moot court	
	Practice & Ethics	Yes

and here one gets more involved in other areas of law, for example, remedies.

The study of remedies derives from the common law concept of "equity" as opposed to "law," which in turn derives from the distinction between the King's Bench and the Courts of Chancery operated by the ecclesiastics in early England. The Anglo-Norman kings, beginning in 1066, developed a system of law which had become hardened into a rigid system (the King's Bench) by the middle of the thirteenth century. Only a very limited number of specific actions (writs) were permitted, and relief consisted only of money damages. Recognizing that money damages were sometimes insufficient, the Courts of Chancery began to grant injunctions (an order to do or not to do a specific act) and other relief.

The system gradually evolved into the Courts of Law and Courts of Equity that persisted until the nineteenth and twentieth centuries. New York first abolished the distinction by statute in 1848. In 1938 the U.S. Supreme Court, by Federal Rules of Civil Procedure, abolished the distinction between actions at law and suits in equity and fused their administration into one procedural system.[2] However, the language, forms of action, and relief tend to persist.

The study of remedies includes injunction, declaratory judgment, specific performance of a contract (as opposed to award of money damages), mandamus (a court order compelling a public official to perform his duty), and restitution. In granting an injunction the issues usually raised are adequacy of the remedy, relative hardship, and delay in bringing the suit. The defenses of mistake, misrepresentation, undue influence, and hardship are generally included in the study of remedies. The material included in the topic of remedies plays a major role in many environmental actions.

Criminal law concerns behavior that is considered to be so negative that its occurrence is detrimental to and punishable by society as a whole. Although an individual may affirm that a crime has occurred, only the public through its officers may initiate a criminal action in the courts. The common law of crimes has been abolished throughout the United States; for a behavior to be criminal, it must be declared to be so by specific statute. Very limited use has been made of criminal law in the area of environmental problems. Such matters generally arise in the way of fines against organizations for pollution resulting from violation of regulatory rules and statutes.

The law of trusts concerns situations whereby a person, as trustee, holds property according to the terms of a trust for the benefit of a beneficiary. Trusts have been used as a device whereby a large number of persons pool their resources to create a trust for the purpose of promoting some environmental cause.

The law of municipalities varies from state to state. Included are the rights to tax, to regulate, and to exercise police power. "Police power" includes much more than the patrolman on his beat. It includes providing utilities, sewage facilities, garbage collection and, in general, any matters relating to the public health, welfare, and safety not preempted by state or county governments. Municipal law obviously plays a major role in urban environmental problems.

Taxation by various taxing authorities has been proposed as a technique for regulating pollution and for transferring the cost of polluting to the polluter.[3] Many practical problems arise in attempting to do so, including the difficulty of equitably assessing the potential damage and the difficulty of obtaining the necessary legislation.

Business associations, especially coporations, have participated directly or indirectly in almost all environmental problems and actions. The reasons are several but do not necessarily relate to corporate law, as such.

In early England favorites of the crown were given licenses, often exclusive in nature, to engage collectively in some business operation. In the eighteen hundreds in the United States, this evolved into permission for groups of businessmen to collectively finance and operate large projects such as railroads. Included was the idea of liability limited to the amount of the capital devoted to the venture. The conventional business of the period was a sole proprietorship or partnership whereby the participants were all liable for the total debts of the business. Corporations were sometimes looked upon by the conservative businessman of that period as a questionable way of doing business. In the early nineteen hundreds, the states successively relaxed their laws governing incorporation. The corporation, as a common form of business operation, came into being. This permitted large accretions of capital, large industries, mass production; and along with the wealth and benefits, came mass pollution.

With the initial uncontrolled use of the corporate form of business came financial instability. This, at least to some extent, led to the crash of 1929. Changes in corporate and securities laws have attempted to reduce this financial instability. However, the corporate objective function remains–to maximize the equitable interest of the stockholders. The principal obligation of a board of directors, by statute and reinforced by court decisions, is to maximize profit and equitable growth of the corporate assets for the benefit of the stockholders. At least in theory, if a director considered public interests over the interests of the stockholders, he would be guilty of a breach of his office and, potentially, would be personally liable.

The Importance of Procedural Law

Statutory rules of pleading (code pleading) have replaced the common law types of pleading. Pleading here refers to the preparation and

submission of written documents to a court in the process of instigating a legal action. It relates to who may successfully present what types of pleading to what courts and for what purpose. The purpose of pleading is to define precisely the parties to an action and the issues of law and fact that are to be resolved. Successful pleading for the plaintiff results in either bringing the case to trial, with the hope that the outcome will be favorable, or to reach a position that appears to the defendant to be so formidable that he settles out of court. Successful pleading for the defendant results in a decision by a judge that no justifiable action exists, whereby the case is dismissed before trial, or to reach such a formidable position that the plaintiff decides to drop the matter.

Terminology varies; the first pleading filed by the plaintiff is a *complaint* or *petition.* The defendant then files either:

1. a motion to dismiss,
2. a demurrer, which says in effect, "Even if everything the plaintiff alleges is true, it still does not amount to a valid cause of action,"
3. an answer which denies some or all of the complaint, or
4. an answer plus a cross complaint.

Depending on the facts, some of the parties (if there are more than two) may be dropped or additional parties may be joined. Also, the judge, type of court, or physical location of the action may change during the pleadings.

Discovery techniques will certainly be used by one or all parties including filing of interogatories (lists of questions which the opponent is obligated to answer under oath before trial) and depositions (examination and cross examination of witnesses under oath before trial). When and if the case comes to trial, both parties will have attempted to maximize their knowledge of the opponent's case. "Surprises" in the modern courtroom are very rare.

Code pleading moves directly into the topic of trial practice, which relates to the conduct of the trial itself. Trial practice involves selecting a jury, strategy in presentation of evidence to support allegations in the pleadings, and the conduct of the trial itself. Trial practice relies heavily on a knowledge of *the rules of evidence.*

The rules of evidence attempt to restrict the trial to those evidentiary matters needed to resolve the issues met in the pleadings. The rationale in the use of rules of evidence is that an orderly and expeditious trial, restricted to matters material and relevant to the issues, will optimize the concept "justice." However, the complexity of the common law and statutory rules of evidence–and their exceptions–is such that both parties have considerable room for maneuvering.

Trial practice generally includes an introduction to appellate procedures. Normally appeals may be made only on questions of law—not on questions of fact. In certain cases, however, an appeal is made *de novo* during which appeal all questions, including evidentiary matters, may be reexamined.

Conflict of laws concerns the situation where a question exists as to which law to apply during pleading or in trial. Potential conflicts exist in many cases as to whether federal or state law should apply and, if state law, the law of which state. Applications to environmental cases usually arise before the pleadings are filed or during the early stages of pleading when the parties are attempting to get the pleadings and trial heard in the jurisdiction with the most favorable rules.

The procedural aspects of law have great importance in the field of environmental law, as indeed they do in all types of legal practice. To say "For every wrong, there is a remedy" is, at least, misleading. Certain matters have been held by courts to be "not justiciable." A typical case might be disagreements between members of a religious sect over matters that could have only a theological resolution. Also, courts, relying on the doctrine of separation of powers between the legislative, executive, and judicial branches of government have declined jurisdiction over matters that should be left to the voters, for example, to resolve.

As for matters in which jurisdiction exists, a substantive legal right exists only to the extent that a procedural method exists for its implementation. If the procedural method is simple and routine, then substantive rights will be obtained easily and routinely. If the procedural method is complex and difficult to achieve, then substantive rights, however beautifully expressed, will tend to disappear.

The Origin of Rules and Laws

Applying effort relative to the origin of laws opens the possibility of adding to, deleting, or revising any or all of the previously discussed substantive or procedural matters.

The people vote for a constitution and for legislators. The legislators pass laws and sometimes, in doing so, create administrative agencies. The agencies make rules which, if promulgated properly, have the force and effect of law. The idealistic separation of governmental powers—legislative, executive, and judicial—is almost nonexistent in many of the administrative agencies that exist on the federal, state, and municipal levels. It has been stated that "the administrative agency is a distinct organ of government unlike any of the other three in that it refers exclusively to an agency which combines all three powers."[4]

Questions raised in connection with practice before administrative

agencies include delegation of power (the National Industrial Recovery Act of 1933 was held unconstitutional on the basis of an improper delegation of power), rule-making power, power to investigate, the licensing function, jurisdiction, right to hearing and notice, enforcement of decisions, exhaustion of administrative remedies, right to judicial review, and the scope of judicial review. Acts such as the Federal Register Act[5] and the Administrative Procedure Act[6] were passed to correct early difficulties with the operation of federal administrative agencies.

Although administrative agencies were often used as mechanisms for reform consistent with the changing nature of society, their growth and power have sometimes resulted in rigidity and loss of procedural justice. In 1954, Jaffe said, "It does not follow from what has been said that today or forever the administrative process is the only instrument of law reform.... The judicial process has not stood still. It has reformed its procedure and reoriented many of its approaches to doctrine."[7] In some contemporary areas of environmental law, the agencies are the defendants and recourse is made to the courts and the pressure of public opinion[8] the influence the administrative agencies toward a more flexible position.

Legislative procedure on the federal level is well documented elsewhere.[9] Municipal procedures are too specialized to discuss in a general article. The legislative procedure for the State of California is outlined in Table 2 as an example of how to use the legislative process in seeking environmental legislation.[10]

Constitutional law begins by studying the wording of the actual constitutions and their amendments. The philosophy of the original writers is examined, and the history of court decisions, relative to social and economic conditions, is carefully analyzed. Constitutional law applies generally to whether actions of the executive, legislative, and sometimes judicial branches of government are appropriate in terms of the wording and/or intent of the applicable constitution.

Proper use of administrative law and procedures and of the legislative process are of major importance in environmental actions. Only in unusual, but perhaps significant, situations does the matter of constitutionality arise.

The Daily Exigencies of Law Practice

One of the greatest constraints on the use of the legal process in environmental matters has been the inability of attorneys to earn a living while specializing in the practice of environmental law. A number of law firms, acting in the public interest, are currently supporting young attorneys who engage solely in environmental areas. However this has an obvious limitation; members of the firm doing the more mundane but

Table 2. Use of the Legislative Process: Summary for California

Legislature convenes at beginning of January.
All bills are introduced during first ninety days of session—except emergencies by 2/3 vote and amendments. No carryovers from previous year.
Only member of legislature can introduce bill—persons seeking legislative change should establish a contact—consider a local author or co-author for a local problem.
Draft the bill—seek assistance from experts.
Keep track of introduced bills—very difficult due to the large quantity—seek help from groups like the Planning Conservation League.
Follow the bill—keep in touch with author and legislative publications—daily journal, weekly history, legislative index, etc.
Bill to committee—most important part of process—Speaker of Assembly or Senate Rules Committee can make or break—try to influence selection of committee—committee cannot act for thirty days.
Bill must go through a policy committee, a fiscal committee, and both houses.
Review membership of selected committees—try to influence favorably by letters, friends, groups, government agencies and reports, other legislators, and personal contacts.
Committee hearing—give author your support—make sure friendly members are in attendance—have people attend hearing to show interest.
Strategy—have amendments ready for author's use—if lack votes, put it over to work out amendments or for interim study rather than defeat.
Floor—three readings before vote—if in doubt, keep up campaign.
Other house—same procedure—amendments may result in selection of a special conference committee.
Passage—both houses plus Governor—keep up campaign—no veto overrides since 1946.

profitable work to support the environmental attorneys will eventually become unhappy and seek to stop the arrangement.

The use of trusts, as mentioned earlier, is a possible solution as are class actions (actions taken on behalf of a group of persons having a common complaint). Both of these have procedural disadvantages and also place the attorney in a situation bordering on advertising. Groups such as the Sierra Club offer a solution but with the difficulty of proving a "standing to sue." This is a procedural difficulty that asks whether the party involved has a claim or injury sufficient to justify *his* bringing the suit. An additional solution is to award court costs and reasonable attorney fees to

a litigant who successfully prosecutes an environmental suit and thereby protects the public interest. Taxpayers' suits (a suit to prevent the improper expenditure of public funds) usually award costs and attorney's fees,[11] as do a number of other actions.

The following example shows how law is gradually changed and concludes this introduction to the legal process.

The tort of nuisance relative to environmental matters has an extended history. For example, in 1705 a defendant was found liable when his sewage percolated into the cellar of an adjoining house.[12] In 1899 pollution of a stream which inconvenienced downstream property owners was held to be a nuisance.[13] Both of these were private nuisances—a term applied to an unreasonable interference with the interest of an individual in the use or enjoyment of land.[14] When pollution killed fish, there was an interference with a public interest; it became a public nuisance; and it was prosecutable by the state.[15] Note that a private party may act on a public nuisance only if he suffers special damage different from the damage suffered by the public, in general. Also a nuisance requires a substantial interference; an occasional unpleasant odor, for example, is not sufficient.[16]

However, a tresspass may consist of a mere technical invasion and, furthermore, is occasionally the basis for punitive damages in addition to the actual damages incurred. The majority of decisions hold that a trespass has to be by a tactilely perceivable object—a rock, a person, a stream of water, etc. Recently, Oregon and California have recognized trespass by fumes, dust, and noise.[17,18] In a 1970 review article[19] Evans and Kratter presented arguments for the existence of "A New Tort: Mass Trespass by Air Pollution," in which they would permit use of a class action. Use of the trespass concept would avoid the need to show special damages and would permit the granting of punitive damages as a deterrent. A legislative approach[20] was presented by Senator Moscone of the California Senate who authored a bill to expand the definition of nuisance to include anything potentially injurious to health, or which constitutes air, water, or noise pollution. It would permit a private person to maintain an action for a public nuisance in certain instances and would permit the person to collect costs and attorney's fees, if successful. All three of the above approaches are probably indicative of a coming trend.

This discussion of nuisance and trespass illustrates the type of legal thinking and development that makes up much of the legal process. General rules of law are formulated from a series of court decisions based on isolated fact situations. A continuing series of legislative enactments parallel the court decisions. They are complemented by changes in governmental structure.

As the social scene changes further, continued application of the rules and laws may yield results that will again appear unattractive. In response to this stimulus, other law review articles will be written; judges will again experiment with departures from precedent; and legislators will again author new bills. This dynamic continuum—too fast for some—too slow for others—is discussed further in the second part of this paper where environmental law is viewed as part of a systems approach.

Part II. ENVIRONMENTAL LAW AS PART OF A SYSTEMS APPROACH

Operations research and systems analysis, like torts, are a more or less unconnected group of concepts. Which concept will be classified as a part of operations research or systems analysis, again, like torts, is a matter of precedent. However, the combined set of concepts that make up these analyses, unlike torts and the common law, have developed very recently. Almost all of the concepts have originated during and since World War II. There are very sparse references to use of the techniques based on these concepts prior to 1940.

The need to satisfy the operational problems of World War II led Great Britain and, soon afterwards, the United States into extensive *research* into the area of *operations* as a general concept. This included optimizing the allocation of resources, the analysis of cooperative and competitive strategies, and the analysis of technical and nontechnical systems. After the war some of the techniques were picked up by industry and government as a means for analyzing inventory problems, waiting line problems, assignment of people and resources, traffic scheduling, and even portfolio analysis.

In all cases the numerical procedures required extensive computations. The growth of the computer industry has been influenced very directly by financial and other gains resulting from the proper formulation and solution of operational research and systems analysis type problems.

In the late 1950's, a concept called *Program Evaluation and Review Technique* (PERT) was developed and implemented as a means for controlling a Navy contract to Lockheed to design and build the Polaris submarine and missile system. In general, defense contracts of the 1950's had already begun to treat the technical design phases of planned projects in terms of a system to achieve an objective. This is to be contrasted to a much earlier approach where in the case of an aircraft, for example, the fuselage would be procured by the government from one manufacturer almost as an isolated object, the engines from another, communication

equipment from a third, etc. Efficiency of the overall system was rarely analyzed–at least in part because of the lack of mathematical techniques and computers.

With the advent of NASA and Apollo, the use of operations research and systems analysis reached a zenith. Without extensive use of these techniques, the operational problems in implementing the required resources and the problems associated with solving the enormously complex technical systems would never have been achieved–not in the required ten years or in a hundred.

One of the few significant benefits to mankind that can be attributed to the earth's collected military and space spending since 1940 are these techniques. However, there remains the task of using these techniques in the solution of the problems of people and their societies. One such application is the use of these techniques to combine legal and technical approaches in the solution of environmental problems. It is to that goal that this paper is addressed.

Application of Techniques to Environmental Law

At this point it will be useful to survey several of the important techniques of operations research and systems analysis and their potential application to environmental law. Although the concepts will be outlined for the nonmathematically oriented reader, it is impossible to completely avoid the language of mathematics.

An application to a simplified environmental problem might be the following description (model) for air *purity*. Let's say that air *pollution* depends only on automobile exhaust emissions which can be reduced by 1) smog control devices, and 2) use of rapid transit systems. The objective is to minimize pollution (i.e., maximize purity). In quantizing pollution we might use, for example, parts of certain pollutants per million parts of air (ppm), or even use some arbitrary but *quantifiably definable* scale of pollution. This could be a scale running from 0 to 1000, where 0 represents pure air and 1000 represents a definable upper limit to allowable pollution. Obviously, air purity would be just the reverse scale–when pollution is 1000, purity is 0, and when pollution is 0 purity is 1000.

Let's further stipulate limits on the amount politicians will require of their constituents to pay for smog control devices and as taxes for rapid transit systems. We will use in our model (description) a maximum cost for a smog control device of \$100 ($x \leqslant 100$), and a maximum tax, over an equivalent period, for rapid transit of \$60 ($y \leqslant 60$). To satisfy the opposition that both may be imposed, we can stipulate that $x + y \leqslant 120$ (i.e., the sum of the cost for a smog control device plus the tax for rapid transit shall not exceed \$120).

Completion of the problem formulation requires a definable relationship between 1) the use of smog control devices and rapid transit, and 2) a reduction in pollution (increase in purity). Suppose that a technical analysis results in the conclusion that z, representing air purity, can be quantifiably related to dollars spent for smog control devices (x) and rapid transit (y) by the equation $z = 4x + 2y$ (the objective function), where z is air purity on the scale 0 to 1000. The complete analytical formulation of the model is shown in Figure 1a.

The problem resolves into the simple mathematical question, "What values of x and y should be chosen so that z is maximized without violating the restrictions imposed on x and y?"

A graphical formulation exists for this simple linear problem involving only two variables (x and y). It is shown in Figure 1b. The constraints show up on the graph as the straight lines labeled with the equations $x = 100$, $y = 60$, and $x + y = 120$. Any combination of values of x and y inside the shaded area are within the constraints placed on the money to be spent for smog control devices, rapid transit, or both. Figure 1c shows the solution using a graphical approach plus some logic. First, select an arbitrary point A within the shaded area to get $x = 40$ and $y = 40$ leading to a value of $z = 240$. The line in Figure 1c passing through point A represents the equation $240 = 4x + 2y$. It now is apparent that as x and y increase, z will increase but the slope of the line representing the equation $z = 4x + 2y$ will remain a constant. The maximum value of z is, therefore, the value of $z = 4x + 2y$ for the line that goes through the corner labeled B. Values of x and y for corner B are easily obtained as $x = 100$ and $y = 20$. Substituting those into the equation for z yields $z_{max} = 440$.

What is the useful conclusion? The conclusion is, if laws are passed with the given constraints, that the maximum air purity will be 440 on a scale of 0 to 1000 and that this purity will be obtained when \$100 is spent on smog control devices and \$20 is spent on rapid transit. For this model any other possible combination of expenditures (that meet the constraints) will result in a lower air purity. If this maximum air purity is still unacceptable then some change must be made in the constraints.

In this problem the constraints were built into laws or regulations governing pollution. Other constraints can exist because of physical laws or because of the expected social reaction to stimuli. In any event, the sample problem shown here is a very simple model (mathematical description) of a real world situation. A realistic model would contain many variables, not just two, and many constraints of differing kinds on the variables. A graphical solution would no longer be feasible, but an analytical technique, the simplex method,[21] is available for linear problems of any size. Use of a computer becomes essential.

This first and very basic technique of operations research is referred to

The objective function:	$z = 4x + 2y$
the constraints:	$x \leqslant 100$ $y \leqslant 60$ $x + y \leqslant 120$
plus the conditions:	$x \geqslant 0$ and $y \geqslant 0$

Figure 1a Analytical Formulation of the Air Purity Model

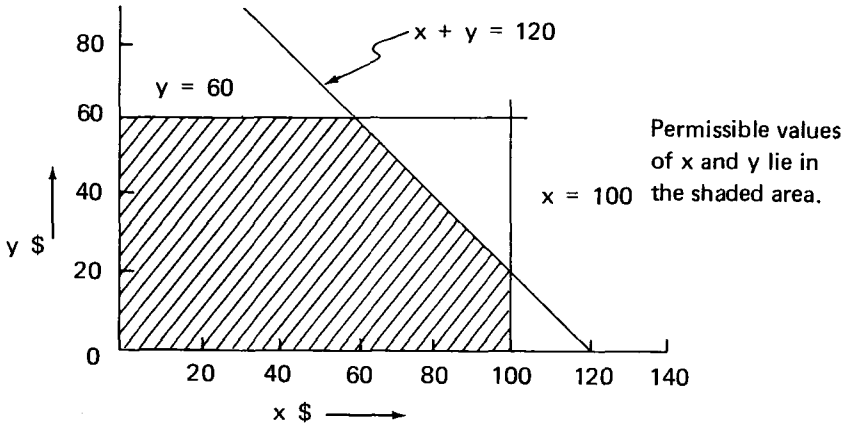


Figure 1b. Graphical Formulation of the Model

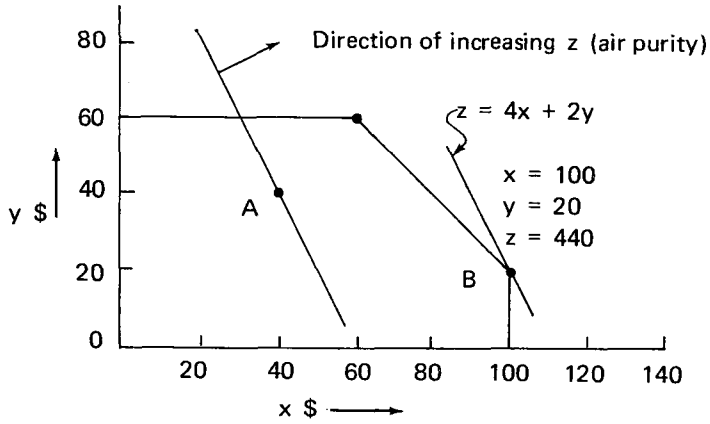


Figure 1c. Graphical Solution of the Model

as *linear programming* and has been used to illustrate an application whereby the impact of a law relating to the environment can be assessed. By predicting such an impact, the law could have been revised so that with proper tradeoffs the degree of air purity might have been much better with no additional increase in expenditures.

It should not be inferred that these techniques are not being used in environmental areas. They are, but only rarely do they include the legal process as a critical element.

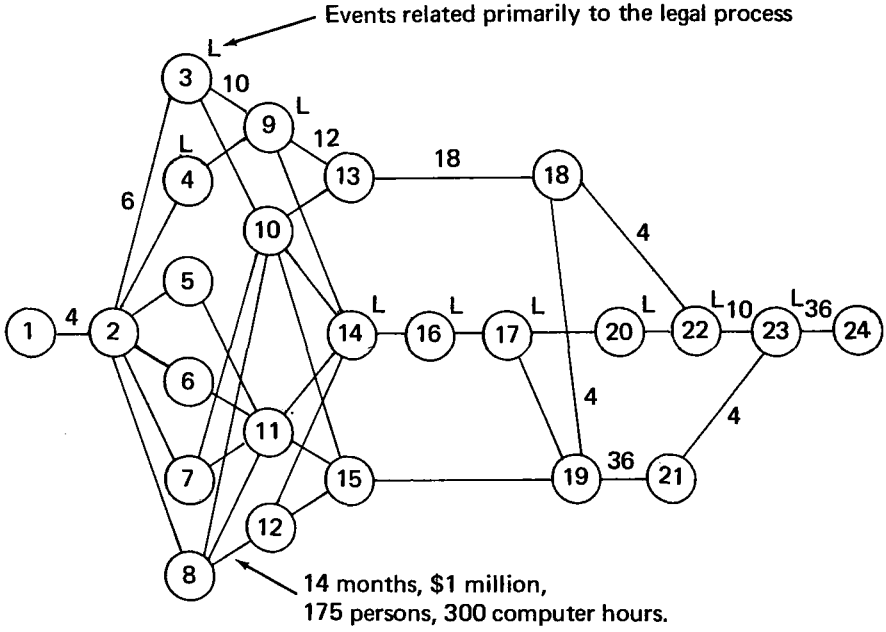
Network Analysis

The next technique to be discussed is network analysis upon which PERT (Program Evaluation and Review Technique) is based. This has been used widely as a technique for planning large, complex operations, in scheduling time, costs, and other resources, in monitoring the results, in assessing tradeoffs, and in guiding the overall operation. An application to a legal-technical-environmental problem is illustrated next.

Los Angeles has an environment, very beautiful on several days of the year, very unacceptable on many days. The prevailing direction of the wind makes the difference—the other factors remain almost the same. These factors include all the environmental factors of population density, air pollutants, water pollutants, disposal of solid waste, use of land, etc. The factors also include the set of rules and laws that directly or indirectly relate to, or fail to relate to, the technical and physical characteristics of the environment.

In developing a master plan for improving the environment of Los Angeles, or California, or the United States, or the Earth, the total system must be considered. As with the aircraft example, where the engines affect the structure of the fuselage and the fuselage affects the performance of the engines, here the rules and laws affect the technical solutions and the technical solutions affect the rules and laws. Some more than others, admittedly, but all to so some degree interact. A PERT chart is one way of including legal matters and their interaction with other parts of the system into overall planning.

A sample PERT chart showing a very simplified plan for changing Los Angeles, say, from its present state to some more desirable environment is shown in Figure 2. The numbered circles represent events that can be precisely defined to have occurred or not to have occurred. The lines connecting the events represent the required effort to get from a prior event to a subsequent event. For example, the line connecting event 8 with event 12 stipulates that event 8 must occur (a condition precedent) before the effort required to get to event 12 can be initiated. The connecting line



1. Initiate conference.
2. Set up study groups for events 3 through 8.
3. Complete study of deficiencies in agency structure.
4. Complete study of deficiencies in legal procedure.
5. Complete study of technical problems—air.
6. Complete study of technical problems—water.
7. Complete study of technical problems—solid waste.
8. Complete study of transportation problems.
9. Complete restructuring plan for regulatory agencies.
10. Complete land use plan.
11. Complete restructuring plan for monitoring technical systems.
12. Complete transportation plan.
13. Make land transfer offers for open spaces and transit system.
14. Formulate proposed laws.
15. Submit requests for proposals for rapid transit systems.
16. Complete public relations program for proposed laws.
17. Pass required laws.
18. Complete land transfers for open spaces and transit system.
19. Let contracts for rapid transit system.
20. Implement changes in agency structure.
21. Complete rapid transit system.
22. Promulgate agency rules relative to the environment.
23. Complete procedures for monitoring and regulating environment.
24. Achievement of desired environment.

Figure 2. Simplified PERT Plan for Achieving a Desired Environment.

can be used to represent the estimated time to complete effort 8-12 (14 months), the cost of the effort ($1 million), the persons required (175), etc.

A scheduling use is shown along the top line where the required time to complete the series of events 1-2-3-9-13-18-22-23-24 is estimated. Adding up these times gives a total of 4+6+10+12+18+4+10+36 = 100 months as the time to completion along *this* path. Along another path it might be greater. For example, instead of going from 18-22-23 a path exists going from 18 -19-21-23 which takes 30 additional months for completion. The *longest* such path from beginning to end is called the *critical* path and represents the *shortest* time in which the completion date (event 24) can be reached. To reduce the time to completion, one examines the events along the critical path and applies more resources in these areas at the expense of less critical areas. As events are completed, new estimates for remaining events are made with the result that new critical paths are discovered. Many texts discuss PERT techniques; the reader is referred elsewhere[22] for more detail.

The emphasis of this example is to show a technique for including the legal process and its interaction with technical matters into a systems plan. By following the circles with a superscript "L" in Figure 2 one sees the central path of the legal portion of an environmental plan. The interaction with nonlegal matters becomes apparent. The need to estimate the time required to formulate and pass the necessary laws–along with estimates of the required cost–is also apparent.

Development of a realistic PERT chart for restructuring the environment of a major urban area would lead to both discouraging and encouraging results. The discouraging result would be the realization of the time and effort that would be required to change an existing major situation. The encouraging result would be the realization that it actually could be done at all.

Game Theory

A third important technique that has relevance to the legal process and environmental problems is game theory. In 1928, John von Neumann did some early research in constructing mathematical models of poker and other games. It resulted ultimately in a corroboration with Oskar Morgenstern (1944) and the rigorous and now classic "Theory of Games and Economic Behavior."[23] A light and often amusing book for the nonmathematical reader is McDonald's "Strategy in Business, Poker, and War."[24]

Game theory presupposes a "game" with two or more players (investors,

poker players, generals, litigants, etc.). The theory also includes the concept that the opponent is intelligent and rational and takes into account that the opponent will capitalize on your mistakes and indiscretions. In the very limited number of "games" that can be mathematically solved the conclusion has been that the optimum strategy to follow is to seek to minimize your losses rather than to maximize your gains. Attempting to maximize gain often results in a situation where the opponent can take a later action and ultimately inflict a serious loss. By minimizing loss you protect yourself from later actions of an opponent—the process of winning involves waiting for *him* to make a mistake. In the case of a "fair," two-player rational game in which one wins what the other loses (two person–zero sum game) the outcome is always a tie.

Games with more than two players and games where all can win or lose (i.e., the stockmarket) are difficult to handle with any present techniques. However the present techniques do enable one to systematically evaluate a complex situation in a rational manner. In the words of Rapoport, "As much as anything else, then, the achievement (of game theory) was in focusing attention on the nature of reasoning involved in the logic of events where conflict . . . of interest enters . . . perhaps for the first time the difficulties of reasoning about typically human affairs has been pointed out and made explicit."[25]

Cooperative games are even more difficult to formulate adequately than competitive games. In fact, in games with a large number of players, the concepts of cooperation and competition tend to merge and sometimes it is uncertain whether a cooperative or competitive situation exists. In the battle of "conservationalists vs. polluters" the sides sometimes become so intermingled one suspects that, like Walt Kelly's comic strip character Pogo said, "We have met the enemy and they are us."

Some potential applications of game theory, relevant to the legal process, are in the pleading and trial of a legal action and in the legislative process. Because of the complexity of even simple examples, the reader is referred to the current literature for numerical applications.

Systems Analysis

A fourth technique, sometimes referred to as "servo theory," "control theory," or, loosely, as "systems analysis," deals with the understanding and control of dynamic processes involving "feedback." Feedback is that characteristic of a system whereby the result (output) affects the cause (input). Such a system must be carefully balanced to avoid erratic system response.

In a physical system, too much feedback (overcontrol) results in

oscillations of increasing amplitude which reach a steady state only if sufficient damping is present to absorb the excess energy. If too much damping exists the system fails to respond internally to any stimuli. The optimum physical system is one in which feedback and damping are balanced so that the system responds as quickly as possible without going into destructive oscillations.

The mathematical techniques of control theory are very well established and have become very sophisticated.[26] It is essentially impossible to mathematically formulate even a simple problem without the use of at least calculus. In applying the theory to the legal process, the difficulty is again in collecting the necessary data and mathematically formulating the problem—not in solving the problem once it is stated.

This technique has tremendous potential application in understanding and influencing the dynamic continuum of the legal process mentioned at the end of Part I of this paper. The block diagram of a simplified model is shown in Figure 3. Responses (eg., motion or energy for a technical system—information or social action for a nontechnical system) flow in the direction of the arrows. The rectangles denote the condition or state of

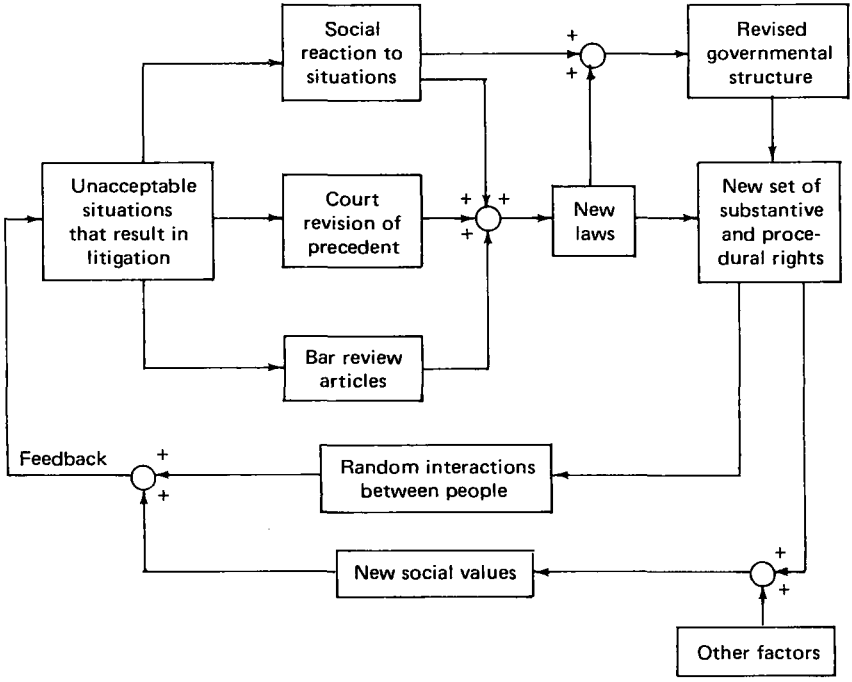


Figure 3. Simplified Block Diagram of the Dynamics of the Legal Process.

different portions of the system. The circles with the + symbols denote that the sums of the output of two or more portions of the system are computed in some definable way to produce the total response or input to the subsequent portion of the system. The essential characteristic showing that feedback exists is the closed loop structure of the block diagram. A system in which all responses flow in one direction is not a closed loop and does not have feedback.

Simulation

The last technique to be discussed is called *simulation.*[27] It is probably the most useful and most general of all the operations research and systems analysis concepts. As used today, simulation is a technique for reproducing inside a computer situations that occur in the real world. Changes are made inside the computer resulting in variations in the computed result. These results are used to infer that similar results would occur in the real world if the same variations were made. The utility of the results depends, of course, on the accuracy of the data.

Unlike the other techniques a formal mathematical model is not required. This says that one need not formulate the functional relationships of a problem. The solution is characteristically not only accurate but it also yields an estimate of what the accuracy is. The disadvantage is that while a person may learn the answer to a given problem he might never learn why he got that answer. However, one can vary the input data and observe changes in the output in order to get an idea of causative relationships. Included in the disadvantage is the large amount of computer time often required to analyze a problem fully.

Almost any kind of a problem, technical or nontechnical, can be solved. The essential ingredients are a large computer and imagination. As an example, suppose one had a wilderness area whose physical characteristics can be well defined—or if not precisely definable, then at least an estimate of the error can be made (i.e., 1000 trees plus or minus 25). Assume also that there exists data on the probability that a hiker will arrive on a given type day and data with an estimatable accuracy on what an average hiker will do during different parts of a day. This data is all put into the computer and the computer is started.

On the first day (in computer time) the computer "flips a coin" that has been "mathematically adjusted" to come up yes or no based on the probabilities of the input data. On the first day the coin may come up yes once and one person comes into the area. On the second day perhaps no one; on the third day maybe eight. Also, on some probability basis, the hikers leave. The computer keeps track of all people in the area and what

they have done. The number of campfires is accumulated, the number of tin cans left in the area is accumulated, etc.

After a year has "elapsed" in the computer the impact of the hikers during that year can be assessed. But that is only one of all the infinite ways that that year could have happened. The computer records the results of that year, goes back to day one and starts all over again. Perhaps the second time four people arrive the first day and the whole series of events and their impact on the area are different. The computer records the results of the year that happened to occur that way. Many years are repeated in quick succession and the average of all the years is then taken. For the reader with a knowledge of probability or statistics it is apparent that enough data now exists to compute standard deviations (a measure of the accuracy) for the averaged results. The entire process can occur very quickly in a modern computer even for a very, very complicated situation. A years worth of events in the wilderness area could conceivably occur in seconds in real time. The whole computation could occur in minutes.

Suppose one wished to assess the impact of a regulation relative to campfires. The assessment can easily be made by including the regulation into the computer's data bank with the instruction that none of the hikers may violate it—or perhaps that a certain percentage will. The entire computation is then repeated; the expected impact of the hikers on the area is again summed up; and this result is compared with the earlier result without the regulation to assess the effectiveness of the regulation.

Because there are no equations to formulate or solve, the simulation may be made as complex and realistic and as accurate as desired. The limitation is only in collecting accurate and useful data and the cost of computer time.

The entire spectrum of legal-technical-environmental problems is susceptible to this technique. For example, one may assess:

1. Changing the structure of administrative agencies,
2. The effect of imposing an obligation on corporate directors to evaluate the impact of their operations on the environment.
3. Variations in court procedure,
4. The impact of awarding costs and fees in successful environmental actions, and
5. The effect in general of revisions in laws.

The real utility in all of the techniques of operations research and systems analysis lies in the ability of rationally quantizing and then mathematically manipulating quantities that to many persons would appear to be "nonmeasurable." Measurements may be based on physical laws or they may be based on an arbitrary but definable scale. Most physical

dimensions in science originated as arbitrary but definable scales. Only after a phenomena was well understood were the arbitrary scales related to general physical laws.

Measurable may also be categorized as exact or approximate. An assumption of exact values and exact laws leads to a deterministic world. The real world is probabilistic and includes the fact that even physical laws do not always hold and that all data and measurements are inexact. A sophisticated analysis treats a problem in a probabilistic way and yields an expected answer plus some measure of its accuracy. For simplicity, the examples included above were given as deterministic models. However, in the usual solution to such problems the computation techniques used yield probabilistic results.

One can make an estimate of any physical, emotional, or intellectual concept with at least some estimatable degree of accuracy and therefore obtain a mathematical solution in a probabilistic sense. That the error in the answer might be so large as to limit its immediate usefulness does not argue against attempting the computation.

Conclusion

The paper has presented some initial formulations of models that combine the legal and technical aspects of solutions to environmental problems using the mathematical techniques of operations research and system analysis. The sample applications were kept very simple and were intended only as indicative of how operations research techniques might be used. The intended emphasis was to show that the sample applications could, with modest resources, be extended to realistic and useful predictive models.

Earlier in the paper a comparison was made between the length of time that operations research has been in existence and the length of time during which the common law has evolved. The one has a history of some 30 years, the other some ten centuries. The comparison is only relative. With respect to the time it takes a tree to fall both are very long. With respect to the lifetime of mankind both are very short. Before the common law there were some ten centuries of evolving Christian law. The Judaic law, back to the time of Moses, predates the Christian era by another twelve centuries. Before this (3000 years ago) the history of man becomes very uncertain. Prior to 5000 years ago the nature of human civilization is almost as much speculation as fact.

There is a tree living high in the White Mountains between California and Nevada that started life 5000 years ago. When Moses walked on Mt. Sinai, the tree was 2000 years old. Relative to the life of this tree the

development of modern law, technology, and environmental problems are very very recent. Yet these factors have collectively and significantly deteriorated the environment on earth and have, in recent years, even caused the disappearance of several species of life form and endangered many others.

Long before the tree existed was the age of the dinosaurs. This prehistoric life form is said to have ended his transient stay on earth due to an inability to adapt to the changing needs of his existence. The age of the dinosaurs lasted some 140 million years. The age of man in his present human form appears to be on the order of 0.2 million years.

Informed persons have made estimates ranging from several centuries to as low as several decades for the continued existence of human society. Given the present state of the earth, the rate at which it is being degraded, and man's inertia for change, some of the estimates may be well founded. Systems techniques offer a method for understanding the complex interactions of society and, in conjunction with other knowledge, provide a useful approach for solving its problems.

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