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INFORMATION AND POLICY ANALYSIS:

A MODEL OF CHANGE.

BY

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A thesis submitted to the Faculty of
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Abstract

Upon consideration of contending models of policy-making, the common problem of information in and of such processes is isolated. Social action is taken to be a learning function, one which undertakes to define and reduce uncertainties. A normative action model of the middle range is based upon levels of information processing in policy-making, information costs, and relations of influence among units. Influence derives from information which informs (supports) choice by virtue of its scarcity and from selective information which constrains choice by making rules (demands). Influence relations thus permit empirical investigation in terms of information networks.

The model is applied to scientific fields. Certain neo-Zipfian distributions of citation data are used descriptively in terms of least costs of information processing. Available results are applied to selected propositions on change and the sociology of science, and their potential described for policy analysis based on subject literatures and research fronts.

PREFACE

Much has been written about change, and change has always been at the basis of politics. To deal adequately with social and political change, some realistic level of social context must be selected and attention paid to processes of interaction within it. Any process of change, planned or unplanned, involves policy in the sense of a programme of action, which may be consciously devised or implicit in the history of the action.

Early in this paper, several models of policy processes are presented. One aspect of each is emphasized: its treatment of information. In so doing, the evolution of a new field of research is traced out, one which has as its aim the provision of information for policy making. This information takes the form of knowledge about the policy process and about the policy problem in question.

On the basis of these information needs of policy makers, the merits and orientations of selected models are presented which indicate the main research areas in policy science. Particular information processing activities appear to be assumed or implicit in widely different models and cases of policy making.

Chapter 2 proceeds to develop a model of policy making within the context of action units and groups of them which

interact. Relations of influence are considered to result from two kinds of information movement: that which influences possible action by constraining it selectively through the imposition of rules and that which influences it by the capacity to withhold valuables. These two kinds of information relate the variables of the action unit and its environment. Social action is taken to be directed to the reduction of uncertainty in some form, hence requiring policy making and learning strategies. Thus, action is modelled in terms of organizational and associational contexts of the middle range; action units are described as open systems structured by the requirements imposed by particular levels of information processing. An arena of action units is similarly linked together by relations of influence and information.

Finally, chapter 3 describes the application of this model to a field of scientific knowledge. Various aspects of the sociology of science are found to be classifiable on the model, and the essential variables of a field of knowledge are isolated in such a way as to permit investigation of their relationships. Empirical definitions cannot be found for all variables - particularly the notion of a 'research paradigm'. However, on the basis of studies which have been made, evidence is found in support of some propositions which relate key variables in the system.

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CHAPTER 1

THE COMING STRUGGLE FOR POLICY ANALYSIS: Competing Models of the Policy Process

Toward the end of the eighteenth century there lived in a village of Leicestershire a boy known as Ned Ludd. His mental derangement made him a victim of the cruelties of other boys in the village. On one occasion Ludd pursued his tormentor into a house containing some frames used for weaving, but, unable to overtake him, Ludd vented his anger by smashing the frames. Afterward, a common saying developed which attributed all broken frames to the work of Ludd.

During that critical time power-driven machinery increasingly replaced manual labour, reorganizing textile production into the mills at the expense of cottage industry. Successive depressions during the war with France coincided with widespread rioting and attacks on the power looms; by 1811-12 the bands of rioters were highly organized over several counties, their leader taking the name 'General Ludd'. By consequence, legislation came down that winter making the destruction of machinery a capital offence. Indeed, Byron's first speech to the Lords in February, 1812, was an impassioned defence of the Luddite revolt.

Though industrial growth was such that alternate jobs could readily have assimilated the displaced, the mill owners instead favoured child labour

over the political uncertainties of apprenticeship in the mills. During a severe depression in 1825 the hand weavers brought on a general Luddite revolt, destroying the new industrial machinery throughout the kingdom.

The history of Luddism may portend our own time in several respects. In the first place, the revolt is truly political in the sense of being directed against conditions of social life rather than at symbols of authority such as individuals or regimes. And, similar to much of current radical thought, it presents a romantic ideology of the past set over against the negative forces of new technology. Ironically, ideologies of individualism are now called up in place of the passing gemeinschaft of Byron and Ludd. Early industrial technology imposed new constraints on social organization and contributed to the development of a radically new world view characterized by an individualist concept of man. Those values of individualism now appear as a common theme in the reactions against new information technology.

But Luddism old or new is reactionary and nihilistic, smashing the machine and denying change along with the possibility for re-designing its conditions. It represents a tormented and desperate rage: an alternative to political action, as if this were the last act. The political system, the nature of power and

the individual, above all, technologies and technique are commonly presumed in current radical thought to be known invariant concepts not requiring further analysis.

In times of fundamental change, where a commonly held world view is shaken along with its technical and social base, we may expect politics to be interesting and sometimes reactionary. In Luddite times, the new industrial society legitimized entrepreneurship and market labour with the ideology of individualism. Today we find the same ideology used in reaction to the normative demands of post-industrial technologies. But for the first time, man actively is engaged on every front in the process of his own evolution. Uncertainties are such that strategic actions which alter the resource base (particularly in science and technology) also alter the conditions of policy-making itself. To avoid the radical tumult of which scenario writers have warned, some have advocated the extension of evolutionary controlling into the political process. This development, fraught at the same time with dangers of an inverted historicism and with hopes for a new liberalism, made its modern appearance first in the political thought of Harold Lasswell.

Some twenty years before his classical notion of the political was again taken up by David Easton, Lasswell said in a paper before the assembled APSA

at Chicago (December 29, 1940):

The general science of politics is concerned with the factors affecting the magnitude and the distribution of values - of influence, with special reference to the distribution of deference.¹

Then he chose to distinguish a general science from an applied science of politics, and thus drew attention to the already developed analysis of different types of political society and elites on the one hand and to the need for applied sciences for the realization of their goals on the other. He saw this distinction as equivalent to that between general physiology and medical science. In the face of wartime struggle, policy sciences would help discover how best to proceed in order to realize democratic values. With a policy orientation, political studies would recall the problem of change to a central place.

Professor Easton has traced this important development within the context of Lasswell's whole output up to 1950, and particularly with respect to his concern for the status quo limitations of a power elite approach and the possibilities for the feedback of democratic constraints in the policy process.

In the writings of Lasswell there is adumbrated the most extreme claim that social science can make. The suggestion appears that to convert political science to a policy science, a discipline contributing to the solution of social

problems, new referential principles are required; there appears in embryo the further claim that even the goals upon which social policy must be based can be established with the procedures of a fully developed science of man. ²

By 1951, when behavioral methods and ideology had begun to appear in political science departments throughout the United States, Lasswell reformulated the two tendencies which had been complementary in his own thought: a general science of the processes which allocate values and applied sciences servicing the information requirements of policy-makers.

A policy orientation has been developing that cuts across the existing specializations. The orientation is twofold. In part it is directed toward the policy process, and in part toward the intelligence needs of policy. The policy sciences includes (1) the methods by which the policy process is investigated, (2) the results of the study of policy, and (3) the findings of the disciplines making the most important contributions to the intelligence needs of the time. ³

The idea of a science of the 'political' - i.e. of the allocation of community values - was thereby differentiated into several policy sciences ranging from the more or less purely scientific study of how values evolve in a community and the processes of distribution, to applied sciences of policy intelligence, design, selection and administration. However uneasily, political philosophy and societal engineering are thus fixed on the same continuum, finding common cause in the diverse

information needs of political processes.

For many reasons, the behavioral persuasion imposed itself in political science with an orthodoxy unknown to neo-behavioralism in experimental psychology and psycholinguistics. In a climate of political exorcism, demands were made throughout the fifties not only that political analysis must be value-free and non-prescriptive, but often that values and norms were not themselves permissible as subject matter for study. Of course, if taken seriously by all, the latter consideration would rule out any study of politics as Lasswell had defined the subject. Despite its timely and needed methodological gifts, behavioralism brought to political science a dispute which, among other things, obscured the development of policy sciences and artificially alienated the two tendencies which we have noted in Lasswell's thought. To be sure, a behavioral study of policy processes was undertaken, but one refusing any prescriptive undertaking and ignoring a host of complementary techniques which were already by the late fifties beginning to pour hard information into the making of defence policies.

To more clearly delineate the area of policy analysis and information to which this paper contributes, it will be useful to identify the major tendencies in policy sciences, emphasizing their treatment of the information problem. In 1.1, descriptive models of

policy making processes are presented. Care is taken to draw out the parallels between a highly rationalized and explicit sequence of decision stages and a model of unplanned basic change. Their implicit emphasis on the problem of information in the process of policy making is followed in 1.2 by Lindblom's incrementalist model, where information is seen as not only desirable, but costly and risky as well, so much so that little or no rational calculation in policy making is advocated.

By contrast, information about the process and about effectiveness of policy decisions comes under scrutiny in 1.3, the behavioral approach. The final section reiterates Lasswell's intention that both kinds of information are necessary and complementary as the basis of study (footnote 34):

As a working formula, I describe the policy sciences as concerned with two separable though entwined frames of reference: knowledge of the policy process; knowledge in the process.

To accomplish this, 1.4 discusses the policy-making action unit in terms of its information processing functions. Various techniques for developing such information in policy analysis are suggested. The basis for a middle range model of policy-making activities evolves within this context.

1.1 DESCRIPTIVE MODELS OF THE POLICY PROCESS

Policies may in general be considered as action programmes. Those which are in whole or in part consciously designed by the action unit are included along with those which involve no planning and result more or less completely in response to unexamined environmental factors or other 'givens' of the situation. If we refer to these as strategic imperatives and technological imperatives respectively, it may be observed that in the real world concrete policies are a function of both kinds of elements. As a model of the action unit is eventually derived, these different influences on policy can be defined operationally. For the moment, they may be classified as two ideal-type policies on either end of a polar gemeinschaft-gesellschaft continuum.

In the use of this classification, it is usually assumed that social action of the gesellschaft type implies a greater degree of overt selection and adaptation of means and ends. For example, some policy or reward for labour prevails for both the tenant farmer and the organized worker. But for the worker to join a union as a means to achieve deliberate ends reflects a greater strategic adaptation of means and ends

than the tenant farmer who derives relatively undefined benefits more or less completely as a result of unexamined past practices. The two policy situations of the tenant and the worker correspond to types of social relations which F. Tönnies has idealized under the terms gemeinschaft and gesellschaft.⁴

Obviously, other variables or sets of techniques must be involved in such a contrast, but the more or less conscious techniques by which the action unit gathers and uses information to achieve its ends are of particular interest here. The prototype of descriptive models of policy-making of the conscious or strategic sort was developed again by Harold Lasswell. In a very early paper on the subject, he stressed the central importance of "intelligence" or information needs:

Policy thinking is 'forward' thinking; it is manipulative and responsible. It is always guided to some extent by knowledge; and a recurring problem is to perfect the intelligence function so that it brings to the focus of attention of the decision-maker what he most needs to think about and what he most needs to think with.⁵

In line with this early emphasis, he eventually categorized the policy process for a single decision into seven functions, as follows:

(1) intelligence or information-gathering for both problem-definition and for policy-design (i.e. the design of alternative solutions);

- (2) promotion or the recommendation of one or more policy alternatives (this would involve influence and bargaining, but also the ideological use of the information);
- (3) prescription or enactment of a solution (i.e. authoritative policy selection and output);
- (4) invocation of the adopted alternative as a provisional rule of conduct;
- (5) application in specific cases (administration of policy);
- (6) appraisal of the success or failure of the policy (feedback); and
- (7) termination of prescriptions and policy arrangements.

Perhaps because he sees policy in the context of single decision-makers, Lasswell does reduce the process to an isolated decision viewed as a highly rational act of calculation. But in this admittedly abstract form, certain functions have been isolated and may be seen to be at least logically necessary to decision-making, even if no separate bureau exists in practice to perform each one.

Along the same lines, viewing policy as a single decision process, another model has further refined the initial intelligence function into three stages:

- (1) recognition of an occasion for decision (a need or opportunity);
- (2) analysis of the existing situation;
- (3) alternative courses of action are identified;

- (4) assessment of the probable consequences of each alternative; and
- (5) choice from among alternatives.

Though Litchfield tended to ignore political considerations in this model, he appears quite sensitive to the importance of the given situation and to the need for information on it (analysis - 2). The appraisal or assessment function was also presented at a point in the sequence before enactment, thus reserving the maximum possibility for the use of information and anticipatory designing in the policy.

Any policy process may be seen as an action programme in the process of being enacted, and it usually implies change of some sort. Any change in a given allocation of values must be critical to politics as defined. But it is clear that values are redistributed continuously and often without any decision or process of rational calculation approaching the explicit sequences singled out by Lasswell and Litchfield. Many change theories do exist to explain these gemeinschaft-like policy processes in terms of conflict, technology, economic conditions and so forth. A descriptive model of particular interest is one drawn from the social action perspective; it accounts for piecemeal as well as structural changes arising from many variables.

In studying the process of unplanned structural change in cottage industry at the beginning of England's

industrial revolution, Neil Smelser discerned a sequence of distinct behavioral stages or types of activity. They bear remarkable resemblance to the rationalized sequence of functions in Lasswell and Litchfield.

A student and collaborator of Talcott Parsons, Smelser adopted a structural-functional view of social action, accounting for change in a particular evolutionary sense.

The model of structural differentiation is an abstract theory of change. When one social role or organization becomes archaic under changing historical circumstances, it differentiates by a definite and specific sequence of events into two or more roles or organizations which function more effectively in the new historical circumstances. The new social units are structurally distinct from each other, but taken together are functionally equivalent to the original unit.⁸

In effect, disturbances and conflicts of any sort might arise and require adjustment or tension management.

But Smelser particularly interested himself in those disturbances requiring structural adjustments (in this context, 'structure' has the sociological meaning of an interactive system of roles; in other words, a working pattern of behavioral expectations). Given an undifferentiated economic and social sub-system such as cottage industry (a relatively gemeinschaft pattern of social relations), then those changes "which involve the disappearance, re-creation and reorganization of the social system's roles"⁹ would be of great political and historical significance. New technologies appeared in the form of power-driven looms. Among the implied alternatives or

"imperatives" of such developments was the reorganization of socio-economic relations into more specialized industrial and kinship functions. The earlier reference to the Luddite revolt attests to the attendant conflicts and disturbances arising from the absence of any strategic policy planning.

Based upon a rather exhaustive review of the historical evidence, Smelser noted the following sequence of activities in the full process of structural-functional differentiation:

- (1) dissatisfaction with goal achievements and a sense of opportunity for change arising from potential resources;
- (2) disturbance symptoms in the form of unrealistic aspirations along with negative emotional reaction to the innovations;
- (3) management of disturbances through the assertion of the existing value system;
- (4) proliferation of resulting new ideas and social innovations without responsibility for their implementation;
- (5) specification of selected innovations in terms of new institutional role patterns;
- (6) implementation of the new structure, with reward/punishment norms attached;
- (7) routinization of the activity into normal social

action, provided its implementation (6) was favourable.

Wishing to reconcile his change model with the Parsonian action system, Smelser proceeded to an extensive and severe categorization of the historical evidence. Nevertheless, as a descriptive model, it has since served usefully to categorize structural change and differentiation (a) of economic function in early cottage industry; (b) of economic function in the modern rural household; (c) of the education and socialization function from family and church to school; and (d) of political function from family and faction to organized party. While these and other structural changes might conceivably result from rational calculation and strategic planning, in fact historically they often follow an unplanned course, conditioned by existing values and the imperatives of whatever innovations or new resources caused the initial conflict.

These selected descriptive models and their corresponding stages may be compared on a chart (Fig. 1) as shown. Three major points may be observed with reference to Figure 1. In the first place, the selected models describe policy processes in terms of stages which alternate social processes of information gathering or generation with social processes of influence, bargaining and

Fig. 1. Selected Descriptive Models of the Policy Process

	<u>Lasswell</u>	<u>Litchfield</u>	<u>Smelser</u>
POLICY DESIGN INFORMATION (pdi)	1. intelligence	1. recognition 2. analysis 3. alternatives	1. dissatisfaction 2. disturbances 3. covert Handling 4. proliferation
POLICY SELECTION INFORMATION (psi)	2. promotion 3. prescription 4. invocation 5. application		5. specification 6. implementation
POLICY OPERATIONS INFORMATION (poi)	6. appraisal 7. termination	4. assessment 5. choice	7. routinization

control. The second point is that in the Smelser sequence of unplanned change, where action units become fundamentally reorganized, the information functions are performed in a primitive and inefficient way. The process is exceedingly slow and only proceeds by way of conflict. For example, intelligence about prospects for change comes in the form of dissatisfactions and disturbances. Information gathering, which is costly and primitive in the Smelser sequence, is rationalized in the Lasswell and Litchfield models.

But this brings the discussion around to a final point: that the rationalized schemes assume information to be costless, or at least they omit discussion of costs and

political bargaining. Moreover, these descriptive schemes assume policy as a single abstract decision, which is again politically unrealistic. To place these models of policy processes into the real world context of continuous and adaptive policies puts an even greater emphasis on the intelligence and feedback information needs of policy-makers.

1.2 INCREMENTALISM: THE THEORY OF MUDDLING THROUGH

To think nothing of symmetry and much of convenience; never to remove an anomaly merely because it is an anomaly; never to innovate except when some grievance is felt; never to innovate except so far as to get rid of the grievance; never to lay down any proposition of wider extent than the particular case for which it is necessary to provide; these are the rules which have, from the age of John to the age of Victoria, generally guided the deliberations of our two hundred and fifty Parliaments.¹⁰

Macaulay's admiration for the political wisdom of English common law and constitutional experience is cited and reflected in the work of the political economist, Charles Lindblom. In his extensive collaboration with Robert Dahl in the early 1950's, policy-making in government, and indeed rational social action in general, was assumed to be based upon two prerequisites: (a) an action unit must make rational calculations about the relative utility of various alternative actions in terms of goal-attainment; and (b) it must have some means of control over other action units.¹¹

The latter assumption of a strategy of controlling is less critical to our interest; it reflects Dahl's continuing preoccupation with the concept of power:

B is controlled by A to the extent that B's responses are dependent on A's acts in an immediate and direct functional relationship. 12

In his interpretation, A and B are individuals rather than any policy-making action units, and in fact, throughout Dahl's part of the discussion they are actors within a political régime. These are not the only limitations in Dahl's approach; the assumption that controlling influence is always a problem of zero-sum strategy is particularly damaging since it omits cooperative strategies (which imply control in his definition), while it includes only the abstract case of perfect competition. This matter will come under consideration again with policy arenas; for the moment, it is important that action units which make policy are at least seen in relations of influence with other action units and that outcomes will involve adjustments among partisan interests.

The other assumption of rational calculation is, for policy, the more important issue, and Lindblom derives it from economics. Unlike the more comprehensive view of policy-making in the descriptive models, where information is more or less costless and complete with respect to policy alternatives for a single comprehensive decision,

we now find that policy is in continuous marginal adjustment and always based upon grossly incomplete and costly information. To begin with, the multiplicity of policy goals makes scheduling difficult, while the partial realization of a goal may change its priority. "Taking these two facts together - that to make rational calculations one must maximize at the margin, and that goals are subject to diminishing marginal utility, it follows that margins are constantly fluctuating."¹³ Moreover, information on the effects of marginal alternatives is scarce and costly. "Knowledge of consequences is necessary if costs and benefits are to be calculated; yet experts do not always possess this knowledge, and 'practical' people are unable to articulate it."¹⁴ His solution extends the theory of market choice into the policy arena.

According to Lindblom, the wisdom of these 'practical people', so praised by Macaulay and Burke, manifests itself in two ways. By political conflict and bargaining, their various partisan interests become expressed and mutually adjusted. (Some of the costs of this deliberate lack of planning were noted in the comments on the Smelser sequence.) Secondly, while calculated risks might occasionally be taken (i.e. when doing nothing carries risks itself), the strategy of practical men must indeed be disjointed and incremental. It's clear that

rational calculation in the real world does not begin
ab nihilo:

It is equally clear that they derive information about alternatives from historical experience, from contemporary experience in other societies or locations, and from imagination stimulated by experience. Moreover, the policy analyst... attempts no more - later we shall show that he attempts even less - than to understand the respects in which various possible states differ from each other and from the status quo.¹⁵

Incrementalism is a method of social action that takes existing reality as one alternative and compares the probable gains and losses of closely related alternatives by making relatively small adjustments in existing reality, or making larger adjustments about whose consequences approximately as much is known as about the consequences of existing reality or both. Where small increments will clearly not achieve desired goals, the consequences of large increments are not fully known, and existing reality is clearly undesirable, incrementalism may have to give way to a calculated risk.¹⁶

Analysis and evaluation are disjointed in the sense that various aspects of public policy and even various aspects of any one problem or problem area are analysed at various points, with no apparent co-ordination and without the articulation of parts that ideally characterizes subdivision of topic in synoptic problem solving.¹⁷

The realism of this model in terms of the politics of interests as well as the economics of information techniques has been borne out by institutional and case studies of policy-making within political régimes. Aaron Wildavsky, a veteran observer of public administration in the U.S., finds that in order to reduce the complexity and costs of rational calculation, budget

officials do not maximize on cost/benefits, but (borrowing Herbert Simon's term) they "satisfice" within acceptable thresholds. It is the inertia of the system which prevails. "The budget may be conceived of as an iceberg with by far the largest part below the surface, outside the control of anyone." Quoting from testimony before the House Rules Committee, he goes on:

If you will read the hearings of the subcommittees, you will find that most of our time is spent in talking about the changes in the bill which we will have next year from the one we had this year, the reductions made and the increases made. That which is not changed has very little, if anything, said about it.¹⁸

This represents a compelling political theory of values distributed in a system merely through its technical operations on the basis, that is, of what earlier was referred to as technological imperatives - technological and resource innovations applied to the inertia of a given organization and distribution of influence. A political function, if one consciously exists at all, is relegated to rule maintenance and brokerage among conflicting interests. However realistic this may appear from case studies of budgetary processes in U.S. government, an invisible hand does not universally write policy. Lindblom has admitted as much in an exchange of views resulting from his 1959 statement of the theory "The science of 'muddling through'".¹⁹

In that paper, incrementalism - it was then

called the method of successive limited comparisons - was favourably contrasted with, in his view, the alternative: a grand theory of rational-comprehensive calculation of alternative means to selected ends. A principal claim was that means and ends are not distinct. One can only agree; the imperatives of a given organization and its technical resources clearly condition any policy for goal-realization which it might pursue.

But the situations are limited where such technical operations constitute the totality of policy making. In his critique of Lindblom's paper, Yehezkel Dror singled out three interrelated conditions which would have to be met concurrently for a strategy of incremental change by successive limited comparisons to be adequate:

- (1) the results of present policies must be in the main satisfactory (to policymakers and to the social strata on which they depend), so that marginal changes are sufficient for achieving an acceptable rate of improvements in policy results;
- (2) there must be a high degree of continuity in the nature of the problems;
- (3) there must be a high degree of continuity in the available means for dealing with the problems.²⁰

Lindblom accepts the applicability of the model as limited by Dror's three conditions. Public policy decision in democracies like the U.S. and in stable dictatorships like the U.S.S.R. would typically call for the incremental model.²¹ But this admission is too general, for the strength of Dror's objection is not merely to point out the need for

risk-taking and radical innovations in policy for modernizing societies, but also in modern societies where, as in segregation, "... changes in values make formerly accepted policy results unacceptable.... When there are no past policies in respect to a discrete policy issue, incremental change is, in fact, impossible."²²

The fact is that few policy situations are stable enough and free of innovation in their resource base of technology and information to meet the conditions of incrementalism. The marginal adjustments which are acceptable as social change in this theory are tied to an implied strategy of maximum security and certainty with minimum risk and uncertainty. The fund of information required is that drawn from past experience of technical operations. By concentrating on agency funding in the U.S. Bureau of the Budget, and ignoring the radically new policy issues which agencies are concerned with, an observer can be overly impressed with the descriptive power of incrementalism.

Lindblom's presentation also contrasts his theory with an idealized and extreme version of comprehensive planning as the only alternative. A host of middle range techniques for rational calculation have in fact been developed, some of which are discussed in section 1.4. Though it has limited application by itself, incrementalism is a recognizable and influential process in cases which involve large scale innovations and other techniques of

calculation. Given its tendency to adapt ends to means, Lindblom's strategy is still a prescriptive theory - it describes, within serious constraints and as a result of technical operations rather than calculation, what ought to be done in a given case. It takes into account the contending political interests in a policy issue. Finally, it does all of these things because of a recognition that information is costly, that feedback information from experience is less costly and more certain, and that uncertainty and risk-taking may be very costly. It is a way of doing policy analysis by negation and by hindsight. Though the incrementalist despairs of rationally calculating alternative courses to desired ends and selecting the best, at least he is confident of avoiding those alternatives with undesirable consequences.

1.3 THE BEHAVIORAL MODELS OF POLICY MAKING

The desire of behaviorists for a value-free science of action encountered particular difficulties in policy studies owing in part to the early influence of Lasswell, his rendering of the political in terms of values, and his orientation of policy sciences toward prescriptive theory. Nevertheless, a line of research has developed with certain concepts which have been used to isolate and deal with selected aspects of policy-making.

The initial conceptual development came with Theodore Lowi's attempt to place various empirical but unique case

studies of U.S. domestic policy-making processes into an interpretive scheme. A sizable literature of case studies had accumulated, isolating different aspects of policy processes such as the role of elites and pressure groups, following a single issue. But, following Lindblom's cautious approach to calculation and his own desire for a general scheme, Lowi claimed "Issues as such are too ephemeral; it is on the basis of established expectations and a history of earlier government decisions of the same type that single issues are fought out." His claim was based upon three assumptions:

- (1) The types of relationships to be found among people are determined by their expectations - by what they hope to achieve or get from relating to others.
- (2) In politics, expectations are determined by governmental outputs or policies.
- (3) Therefore, a political relationship is determined by the type of policy at stake, so that for every type of policy there is likely to be a distinctive type of political relationship.²³

A scheme to accommodate various cases and issues would, he reasoned, follow from types of policy outputs defined functionally in terms of their impact or expected impact on society. Such expectations would normally be based upon past experience, as in the Lindblom model. However, there is nothing in the model to deny that they might be based upon rational calculation of consequences by any information-gathering techniques available to policy-makers. The

behavioralists did not take up this possibility, except where, in a study by Schooler, scientific advisers as a group are considered as a dependent variable.²⁴

Lowi's reflections led him to distinguish three such categories of policy types: distributive, regulatory and redistributive policies. Each of these is enacted in a distinctive 'policy arena' or 'arena of power', with corresponding political processes, elites and political structures and group relations. To be more specific, the policy arenas were characterized by anticipated impact as follows:²⁵

The distributive policy arena: government policies of this sort, such as those made up of patronage or research and development contracting decisions, exhibit considerable ease of disaggregation. They are dispensed unit by unit, treating separately the interests (or relevant action units) which are indulged or deprived. Regulatory policies, on the other hand, may not be disaggregated, nor, consequently, individual interests treated separately. Rather, rules are set for the conduct of action throughout a whole sector of interests while the administration of such rules may be on a case to case basis. In this arena, interests confront each other and bargain for favourable rule setting.

Redistributive policies also affect all the interests of a sector of society taken together. But, as in the case of income tax and other laws which directly redistribute the

wealth status and influence of whole sectors, such policies at the same time affect other sectors.

Using this scheme, Robert Eyestone subsequently reviewed New Deal policies for agriculture and labour, and in order to account for the case where government programmes with respect to a sector of society are substantially left to the sector itself to determine, he added the type of self-regulatory policies.²⁶

A critical item in the use of this typology is the notion of a sector of interests. The single interest, such as an individual or a firm, is identical to what is elsewhere in this paper given the sociological term of 'social action unit.' Such units are goal-seeking, and the policy arena in which they act and interact, assuming Lowi's claim, is determined by the particular goals or values at issue. 'Sector' thus used is a derivation from economics.²⁷ firms are part of the same industry (i.e. they share the same market sector) if they supply similar or substitute goods and services at comparable prices. An assumption thus is made of market interaction and the level of commonly held information about available goods in the market. This assumption of information in a sector of action units pursuing government contracts is important and has not received attention in the literature on the behavioral models.

The concept of a sector, and hence of arena, has

still not, by this approach, been successfully defined in an empirical sense. It is not really possible a priori to decide what action units are in an arena. As the case studies are historical and the definition involves expectations of impact, researchers have reasonably but subjectively approximated arena boundaries by looking at statements of policy intentions and at historical information on actions of affecting interests.

Without attempting to detail the various studies which proceeded from Lowi's initial work, the classificatory concepts have evolved into a working paradigm. That is, relations among the concepts are depicted, so that more than a descriptive model is implied. The difficulties of empirically verifying such relations (since a given policy issue might involve several arenas) do preclude for the present the description of the paradigm as an empirical model. The basic idea of types of policy arenas, defined by expected impact, results from several propositions about the interaction of two key variables. On one hand, the behavior of the government 'decisional system' which makes policy may be more or less fragmented and may operate more or less directly and coercively. On the other hand, another group of variables can be isolated with respect to behavior of interests in the arena, i.e. the 'demand pattern'. Robert Salisbury provided the basic

version of such a paradigm. Lowi's typology for the case studies could thus be described, as shown on Fig. 2, in terms of the relations of 'demand pattern' with 'decisional pattern' variables.

Whereas Lowi had dealt at length with the impact sector (or demand pattern), Salisbury discusses the many political system variables involved in the decision system side of the case studies under review. The decision system is a variable too, or rather a collection of them. In particular, he emphasizes that while there is usually consensus and integration when decisions come down, what is important is the extent of the struggle - the difficulty or cost of achieving such a coalition. The diagonal lines of Fig. 2 are intended to indicate this idea. They connect policy types which are allocative and confer benefits on an interest or sector directly (distributive and re-distributive) and policy types which are structural, establishing authority structures or rules to guide future allocations indirectly (regulative and self-regulative).

The more costly it is to organize the requisite coalition on an issue, the more likely it is that the policy outcome will be structural rather than allocative. 29

But there is no need to assume that the decision systems costs are fixed for any issue. As noted in 1.1 and 1.2 above, the ways by which information is collected, either incrementally through conflict and experience or by techniques of rational calculation, affect the policy process and its costs fundamentally. This matter had been ignored in the behavioral literature, but in a 1970 paper, Dean Schooler speculated on the impact of technology on policy-making:

Impacts will be either redistributive, regulative, self-regulative or distributive depending on how politically significant groups or individuals perceive the technology to affect important values. Thus a policy building upon or employing a particular technology may readjust wealth, status or power among major groups; require or prohibit certain activities; allocate desired values to individuals or groups; or enhance or allow individuals or groups to shape their life styles or public policies affecting them.³⁰

Though he maintains an idealistic view of technology's impact, Schooler's concern indicates an expansion to policy goals and sectorial impact from policy-making structure and its analytical and information capacity.

A formulation of the model, which is yet more general than that of Salisbury, attempted to avoid the abstract quality of policy types defined on anticipated impact rather than classified by content. For this purpose, Lowi's concept was differentiated into three parts: particular policies, policy outputs, and their impact. On this view, formulated by Sharkansky,³¹ policy refers only to actions taken by governments, policy outputs refers to levels of public services affected by these actions - that is, benefits or services per client - and policy impacts refers to indicators of the affect of the service on the population. Environment refers to socio-economic and political variables of the society.

With such a model, no direct relation of policy to impact needs to be assumed. Each cluster of variables is

Fig. 3 Behavioral Model of Policy Process³²

indicated empirically, often from census data, and relations, where they exist, can be discovered by correlation. Thus, in a study of 163 Georgia school districts, services per client were indicated by spending per pupil, percentage from local revenues, teachers per pupil, percentage substandard instruction rooms and other variables. These were correlated (very weakly as it turned out) with impact indicators such as percentage who graduate, percentage who drop out, percentage with daily attendance, etc. Correlations within clusters of indicators were made to show internal coherence. What was found, contrary to or apart from the intentions of policy for education, was correlation of favourable impact with some of the seemingly unconnected environmental variables (examples of these are health service levels, personal income per capita, percentage educated adults in the population, voter participation and others). Another study of state and local governments found, for example, in transportation policy, a negative relation between levels of highway spending on one hand and

rural mileage per capita and traffic safety on the other.

For crime and other policy issues alike, Sharkansky observes:

It is unlikely that high (or low) spending brings about high (or low) crime rates. The incidence of crime probably works upon the spending level The evidence is also discouraging for the expectation that an increase in spending will produce a clear improvement in services. Only 10 out of 27 measures of 1957-1962 changes in services showed sizable positive relationships with 1957-1962 changes in spending. 33

These authors use such findings, which are in themselves behavioral and non-prescriptive, to conclude in favour of incrementalism. Their strength apart from putting many issue cases into a contextual scheme of policy process has been to test out propositions implied by policy intent. While incremental budgeting adjusts spending on a single item upward or downward on experience-related information on the single issue, it should be argued that the correlation of desired impact with quite other policy issues calls for wider information gathering and efforts at coordinating policies for related issues. Indeed, the model itself could be used as just such a prescriptive technique. However, the incremental and behavioral views alike shun rationally calculated, prescriptive information in favour of tacit or process information. Ironically, they do so on grounds of lower decision costs.

1.4 THE BIAS OF INFORMATION IN POLICY ANALYSIS

The model of disjointed incrementalism and partisan mutual adjustment of means and ends has been justified on empirical and utilitarian grounds. It was found to explain in a realistic way the politics of budgeting in cases of stability, satisfaction with and continuity of policy, and relative lack of change. Given those conditions, its strongest appeal was to the criterion of utility: the costs of reaching decisions, of formulating and adjusting policy, are less, so it was claimed, when calculation is left to incremental adjustments within the scope of normal operations.

The utility of such a model was much enhanced when Lindblom contrasted it with one alternative - a single comprehensive strategy of rational calculation. What he ignored was the possibility for rational calculation in models of middle range scope. The desire not to be prescriptive, mixed with two inter-related assumptions - that policy is made by individuals in government and that the environment or policy arena is placid and known - combine as conservative forces; they encourage blindness to the prescriptive nature of information in and of the process, the presence of many policy-making units, conditioning each others' goals and strategies to create turbulent conditions which can be controlled only by information-gathering and risk-taking.

The struggle for policy analysis is thus represented by the tendencies noted by Lasswell at the beginning of

research in policy sciences. Among elaborate and contending theories of description or prescription, it comes down to what sort and how much information is required, how costly to obtain it, and how one wishes to use it. Fields of knowledge are distinguished not merely by differing research goals and social organizations, but also by distinctive methods and paradigms which may often solidify and become relatively unchanging as a world view. It is entirely likely that the development of policy sciences has long been delayed by competing paradigms of the sort already described. Surveying the field after twenty years, Lasswell re-iterated the need for an integral view based on policy information:

As a working formula, I describe the policy sciences as concerned with two separable though entwined frames of reference: knowledge of the policy process; knowledge in the process.³⁴

Referring back to Fig. 1 and to the ten stages of policy processes which were singled out by Lasswell, Litchfield and Smelser, one can discern several kinds of policy information being generated.

(1) In the design or re-design phase (stages 1 to 4 on Fig. 1) intelligence of new opportunities, or feedback on actual innovations or disturbances, are translated into a general problem area, followed by speculative information (politically or rationally derived) about values or goals to be pursued by the action unit. With respect to this general policy area, alternative specific policies are designed and information is

developed about the implied alternative future states of the action unit and its policy arena.

(2) Then in the next three stages on Fig. 1, a second kind of policy information is required; this is a phase where specific policies are selected. Policy-makers must develop information to compare, either marginally or comprehensively, and to choose from among the alternative designs. In the promotion of alternative designs, policy information is likely to be used not just to calculate, but also for ideological support.

(3) In the final three stages, an operational or administrative kind of policy-making is being attempted. Here, there is the need of feedback information for adjustments in particular routinized operations and for the coordination and evaluation of programmes in the light of the overall mission (the goals of which were to have been clarified in (1).

To operationalize a policy always requires fairly extensive interactions with resource markets, and information about these is often costly and important to the overall mission.

Though our emphasis here on the information needs of policy-making has led to sub-categorizing the process into three kinds of information handling, it should be noted how they correspond with other schemes. Incrementalism clearly limits itself to operations, disregarding more comprehensive levels as too risky and uncertain. The behavioral model (Fig. 3) distinguished government actions in terms of service

outputs (or operations) and policy impacts. Both also ignore policy goals along with design and selection techniques, though consideration of these as variables would not logically be excluded from a behavioral model. Impact variables did, however, receive much attention, as in Lowi's work on types of policy arenas (Fig. 2), and this could be useful in terms of performance feedback information and even, as noted earlier, information of wider variables to be taken under consideration.

The notion of levels of policy-making, based on other than information-handling criteria, appears in the work of Erich Jantsch on policy planning. "Policies," he says, "are normative expressions of future states of dynamic systems."³⁵ Moreover, this new conception of planning differs from those of the past just because it includes normative thinking and system design, and specifically it consists of "a conception of three levels - normative or policy planning (the 'ought'), strategic planning (the 'can'), and tactical or operational planning (the 'will')." He derives these three levels from organizational functions; they so correspond with and complement the information-handling levels derived above (provided we do not assume that these functions ought or can all be performed rationally), that the description should be quoted in full:

There are three levels of functional relations between a plan and the environment:

(a) Policy making functions which result in normative planning and are directed toward the search and establishment of new norms that will help define

those values which will be more consonant with the problematic environment. In other words, normative planning occurs when the purpose of planning action is to change the value system in order to achieve the required consonance with the environment. The statements of normative planning are derived from values and defined in terms of 'oughts'.

(b) Goal-setting functions which result in strategic plans wherein various alternative ways of attaining the objectives of the normative plan are reduced to those goals which can be achieved given the range of feasibilities involved and the optimum allocation of available resources.

(c) Administrative functions which lead to operational planning wherein the strategies that will be implemented are ordered in terms of the priorities, schedules, etc., that the situation dictates. Operational planning is that part of the planning structure in terms of which changes in the environment are effected that are purely of a problem-solving nature. (in other words, operational planning need not involve a consideration of value premises.) 36

To be sure, he is not careful to specify the degree of comprehensiveness, nor the amount and costs of rational calculations of alternatives. But with this type of approach, a more realistic theory of the middle range can be developed, not only with respect to levels of decision-making, but in terms of the organizational context within which policies in the real world are made.

Yehezkel Dror has further clarified several concepts which apply to levels of policy-making in what he refers to as a 'prescriptive-preferable' model:

Policy analysis is an approach and methodology for design and identification of preferable alternatives in respect to complex policy issues. It provides heuristic aid to better policymaking, without any presumption to provide optimization algorithms. 37

Then, as a preliminary subdivision, he has broken analysis into design and selection phases. Policy design "deals with the invention and construction of new alternatives"; policy selection "deals with the identification of preferable policies, from among available alternatives."³⁸ Emphasizing the different information requirements, we have adopted this distinction, including intelligence of a policy issue with policy design, and adding operations as a third phase where selected programmes are administered.

A model of the middle range has yet to evolve out of these developments. A single model would not necessarily be desirable in any case, given the variation in policy issues and arenas, and particularly if it were tied to any particular methodology. A host of techniques exist for providing these different levels of policy information, and any model should be able to accommodate available information-gathering techniques, to indicate further methodological requirements and to generate propositions for the testing of validity of essential aspects of the model, relevant to the policy issue at hand. (Ch. 2 & 3 present such a middle-range model based on information processing.)

Existing techniques have been drawn from several fields, often by policy-makers or their advisers in order to fill specific information needs. Systems theory along with welfare economics and decision theory have been particularly fruitful sources. Were one to review the literature at length, a major theme would undoubtedly revolve about the incrementalists'

use of conservative political theory and the economics of bargaining and pricing, set over against the rationalists' use of utilitarian political theory and its modern derivatives: welfare economics, decision theory and gaming. Anticipating some of this theme, Professor Braybrooke sought at length to present incrementalism as an alternative strategy to the felicific calculus of Jeremy Bentham³⁹. No attempt can be made to describe these techniques except in the most general sense in which they provide information to a middle range normative model.

In policy design, information is needed on new issue areas, disturbances and innovations. Brainstorming techniques, social indicators and the political system itself may provide such mission-related information, in what Ozbekhan and de Jouvenel call the look-out function. The normative implications of innovations and the value or goal clarification of alternative policies may be discovered from the use of Delphi or other futures techniques (Rand), scenario writing (Hudson Institute), utopian thought, or social experimentation. Technological forecasting methods often deal with the spill-over or transfer effects on secondary fields.

Policy selection calls for a more rational, preferably quantitative calculation of alternatives. Thus we find the use of systems analysis techniques such as programme budgeting (PPBS), and network analysis (PERT and Critical Path Methods), along with discounting, cost-benefit analysis

and operations research, gaming and simulations.

Some of these, such as PPBS and PERT, are also useful, though within definitely limited constraints, in clarifying missions and designing policies to fill them, as well as for feedback on their operations. However, incrementalism is clearly the most prevalent technique at the operational level of policy-making, and information on this comes from normal census and socio-economic indicators. Behavioral process information is also needed when institutional and organizational changes are being considered to facilitate operations.

As noted, some of these are more comprehensive and supply information of different kinds. Erich Jantsch has a scheme for technology transfers which locates various categories of impact of a technological innovation. Accordingly, he has listed a host of information techniques on the basis of their ability to project the transfer effects of an innovation on a given impact category.⁴⁰ A related "technology assessment" literature entertains a similar scheme of impact categories, broken down basically following Dean Harvey Brooks. Any social or technical invention may give rise to a new product or process (an innovation) and may be transferred vertically through levels ranging from basic science through technology, user organization and society. (Jantsch and others tend to assume only vertical movement of influence from

pure to applied, but obviously, as in the case of the steam engine, an innovation may occur anywhere and transfer upward or downward.) An innovation may also transfer horizontally through other organized activities of the same type - for example, transfer of a finding to other fields of science, or transfer of a technical application of, say, computers from military to other social organizations.

Transfer projections are at the basis of technology assessment, and such schemes (they are really matrices rather than models) have thus far been useful for setting up social indicators and organizing policy-relevant information. Obviously, one cannot ultimately project the entire range of impact of an innovation, though simulations are possible within a well-specified group of parameters. (For example, the SST policy issue was much illuminated by an MIT simulation of its effects on variables of the high altitude environment.)

What seems still required for a middle range prescriptive model of policy-making is recognition of the following: (a) the importance of political factors in any issue; (b) recognition that many action units - most of them non-governmental - make policy with respect to an issue; (c) policy-making takes place inside an organizational context; and (d) the central activity of policy analysis is neither incremental nor comprehensive planning, but rather how to generate and handle costly information.

CHAPTER 2

AN INFORMATION MODEL OF POLICY MAKING

Policy making for the realization and distribution of political values has been presented as a more or less rational set of information-processing activities, each oriented to the major tasks of policy design, selection and operations. This goal-oriented activity is designed and carried out by a discrete construct: the action unit (ref: 2.2). It may involve one or many individuals, but it isolates the part of their activity which is structured: that is, a role-structure or a pattern of behavioral expectations integrated by a communication system of some type. Many action units typically make policy with respect to a given issue. While there is potentially a special character to policies made by action units attached to government, owing in part to a regime's monopoly or at least predominance of violent force, the fact is that it can only rarely be used to administer policies, and then just in the short term. Influence, on the other hand, of which governments have no monopoly, is universally an instrument of policy. The following section (2.1) inquires into the source and kinds of influence.

While many action units make policies with respect to an issue - and in attempting to carry them out, influence and constrain each other - the intended scope of their strategies differs from one unit to another. In the market for automobiles, an inventor with a new fuel cell device takes out

a patent and tries to sell to a manufacturer. But acting only in a limited context to maximize his own welfare, he might conceivably alter many transportation policies quite radically. A division of the company takes up his device as part of a new strategy to increase or perhaps entirely to re-define its share of a market. This action alone would seriously condition the resource markets for engine materials. Consumers, on the other hand, act in different contexts. Individuals may buy this car because the fuel cell uses cheap natural gas in an efficient way. A significant market trend, or anticipation of one, would lead other manufacturers to change their policies, discrediting the new device or adapting to a slightly differentiated product. The market for petroleum products would, of course, be altered radically. But consumers act on other levels as well. Relevant government agencies, assuming they are not completely staffed with company representatives, will be interested in issues of environmental quality and resource depletion as criteria for their policy making. If not, ad hoc consumer representatives and other organizations may lobby to achieve the same effect. Though, in this industry, agency policies are often laissez-faire, the scope of their action or inaction may include all car manufacturers, perhaps the whole market including consumers, or, as for a tax agency, the whole economy. This range of action units, constituencies and markets coming to bear on an issue is difficult to handle.

A really wise government of course would initially have made policy (using taxes and other instruments) to effect the transfer of the innovation from its initial development (in this case, aerospace) to private and public transportation sectors, as well as to housing and other issue areas. The complexity, just in isolating the objects of policy at a general level, might be overwhelming.

To simplify the task of dealing with various policy-making units acting in different contexts, we may invent a generic term: political spaces. The pursuit of any socially shared and thus political value involves goal-oriented strategies or policies for its realization by those who value it individually or collectively and an information network for interaction. All such action systems define political spaces, 'space' being adopted because it is a neutral term definable by any set of parameters; a political space is thus a construct which is empirically discoverable by investigating the information network which structures action within it. A decision not to alter current action, or not to act at all, for whatever reason, still is considered a policy decision. The development and operation of such policies has been represented here as a more or less rationalized set of information-processing activities. Thus, the simplest value, pursued only by one or a few, calls into existence one or more information networks.

The solitary hunter, for example, pursues a fairly

elaborate strategy to gather information on the probable location of game. Weather conditions, tracks, hounds and perhaps a telescope will aid in this task. But were there others in the hunt, they might together bring about a division of labour and even scheduling of sub-goals (cooking, or care of the rifles and hounds), or on the other hand they might be competitors for the same scraps of information and the same game. Even the single hunter pursues what must be a social value, for the knowledge of what categories of animals constitute game is culturally and even legally relative. The game warden, policing the rules of the game, pursues information in this network of hunters, in order to act responsibly in another more inclusive network. The policy goals which he administers have to do with the control of all animals which might be hunted.

Thus, any social value may become the subject of a more or less active policy information network. A class of such values may well become the subject of regulation and hence of a rather more inclusive network. All such networks constitute political spaces. Action units, policy arenas and whole regions of interconnected arenas may be examples of political spaces. The minimal constituents of a political space are (1) its structure, consisting of an information network, and (2) its 'learning strategy', or minimal form of policy, by which is reduced the uncertainty connected with

realizing a value or set of them. (This point is developed below.) In the case of policy-making action units, active policy designing may also be carried on (see 2.2 below). A range of influence is involved in such spaces to be sure, since a shared value is being distributed. But rather than distorting the particular usefulness of Lowi's term - the arena of influence - the generic concept of political spaces, applicable to every case, is preferred. It is also methodologically preferable to deal with information networks, since though they are constructs, they do in principle have a concrete discoverable reality. For policy arenas as described by Lowi (1.3), the intentions or expectations of future impact on the part of significant political actors requires some form of subjective judgement.

Given any social value, a range of action units may be inferred, each one processing information relevant to the realization or distribution of that value. A host of other values must often be involved in the realization of goal-values. The concept of an information network permits consideration of exchange systems which involve exchanges of values other than knowledge. In Section 2.1, these are discussed in terms of the influence to which they give rise, and accordingly typed as information (which informs choice) and selective information (which constrains

choice). From this basis, the model of an action unit is built up in 2.2, drawing on the discussion of information processing functions in 1.4. Networks which link action units into empirically discoverable policy arenas are taken up in 2.3. The most important political fact about such networks is that policy-relevant information is not free and does not move freely through the network.

2.1 INFORMATION AND INFLUENCE

That information in a policy network does not move freely, is always incomplete and very costly, that is not a technical problem which ought or can be ultimately resolved, though it might be altered. The fact that information in any network is imperfectly shared and exchanged at costs encourages a plurality of action units in any political space. Information thus moves more freely within networks; costs rise significantly across boundaries. Thus, we may expect networks to be discrete. (See also the discussion in 2.3.) Moreover, there is a premium on the development of unique information with respect to any value. This also encourages the formation of sub-goals and their networks. It is precisely such policy-relevant information held by an action unit which determines the extent of its influence over others.

The last statement is critical; evidence for it is to be found in McCleery's study discussed in this section.

It should be possible to test its validity, and that 48
of related propositions, when a model for
information networks is completed. The kinds of information
that may exist in such networks is a first step; it will es-
tablish the kinds of influence relations which are to be
expected.

In effect, the position taken here with reference
to the incrementalist view in sec. 1.2 is that rational
calculation yields information which in turn is the source
of influence or control in Dahl's sense. The idea of an
arena of influence surrounding any policy issue was presented
as one particularly useful but equally difficult to opera-
tionalize, since it is tied to expectations or attitudes on
the part of 'politically relevant' actors (and in practice,
particular policies do fall within more than one type of
arena). The information network surrounding a value or a
class of them should, on the other hand, turn out to be a
more researchable phenomenon and one easily permitting the
interaction of a host of policy-making action units.
The central notion of information must be specified more
clearly, along with its relation to influence. To do this in
the most straightforward way, one may point to the particular
ways by which one may be informed.

The environment which could be perceived by an
action unit must be characterized by its complexity and un-
certainty. As actually perceived, however, the environment
is highly structured, and the uncertainty is limited and selec-
tive. It is assumed that the function of any action unit is
the reduction of uncertainty.

Every human organism lives in an environment that generates millions of bits of new information each second, but the bottleneck of the perceptual apparatus certainly does not admit more than 1,000 bits per second, and probably much less. Equally significant omissions occur in the processing that takes place when information reaches the brain. By the same token, there are hosts of inferences that might be drawn from the information stored in the brain that are not in fact drawn. The consequences implied by information in the memory become known only through active information-processing and hence through active selection of particular problem-solving paths from the myriad that might have been followed.¹

The simple physical conditions of an individual's capacity to process information - and this is an equally limiting factor for organizations as well - amount to two things: (a) the environment is complex and uncertain, and (b) this uncertainty must be reduced to permit survival. Therefore, the reduction of uncertainty, or learning, which is here taken to be the universal quality of action, is accomplished by transferring, recalling, processing or otherwise generating information.

But what in fact constitutes uncertainty and information in the real world? To ask "what information does" and reply, "it reduces uncertainty," is less than satisfying, since the referents to 'uncertainty' must be without limit. It is possible to isolate two types of information which may inform in two qualitatively different ways. They derive from the resolution of an apparent paradox associated with Bertrand Russell. Someone says, "I am lying"; then how may we know if he is telling the truth? The key is whether

the statement is taken as a message, or as a message about a message. Gregory Bateson, an anthropologist whose writings have reflected the impact of information science from its beginning, writes that the paradox "can be traced to a confusion of levels of abstraction. The three words which are all we have to go on, are simultaneously both a statement (level 1) and a statement (level 2) about the falsity of this first statement; and the second statement is of a higher order of abstraction than the first."² Thus, the level 1 message, "I am lying", is constrained by level 2, the rule for interpreting all messages from that source.

In order to distinguish the semantic content of messages from aspects of their code (level 2), early communication engineers developed a measure for the latter which indicates the relative unexpectedness of a message from a set of possible messages. D.M. MacKay termed such information as is conveyed by a code selective information, since it refers to "that which determines choice."³ The distinction was primarily made by Claude Shannon during World War II as a contribution to a theory of secrecy systems.

To use the system a key is first selected and sent to the receiving point. The choice of a key determines a particular transformation in the set forming the system. Then a message is selected and the particular transformation corresponding to the selected key applied to this message to produce a cryptogram. This cryptogram is transmitted to the receiving point by a channel and may be intercepted by the enemy.⁴

The ability of an intelligence officer to derive the ordinary information in a secret message may be of great value and result in corresponding influence. But a cryptanalyst may be able to derive the key by which this and similar messages are coded. In so doing, he acquires selective information as well as knowledge of a particular secret message.

From this point of view, information exists only when there is a choice of possible messages. If there were only one possible message there would be no information ... Information is closely associated with uncertainty.... If I was certain of what you were going to say, I obtained no information by your saying it.⁵

That which determines, or in some way constrains possible choices, informs the decision-maker by selective information. A highly redundant language such as English is relatively unconstrained by rules; it permits variety and imperfections among speakers by lowering its selective information. For our purpose, policies or action programmes contain selective information. They consist of explicit rules or guidelines or demands which constrain the ways by which policy goals or values are to be realized. The influence which is exercised in the setting of such constraints can be termed selective influence.

On the other hand, considerable influence of another kind accrues to actors which, while they do not set rules and make demands, do supply resources, valuables, knowledge and other supports in response to demands. With

respect to particular policy demands, these supports convey information in the non-selective sense. The power to withhold information which is needed for particular learning strategies or policies is influence in the non-selective sense.

A political space was defined as a policy information network. The two distinctive kinds of information constitute what is exchanged in a network, and the relative influence of actors depends on their abilities to generate selective information and to withhold ordinary information.

This explanation of political influence is somewhat novel, though there are precedents for the approach. In 1.2, a familiar idea of political influence was introduced, citing from Robert Dahl. An individual A has functional control over B to the extent that B's responses are dependent on A's acts. Dependence on supports of various kinds is a form of influence commonly exercised by all action units in an interdependent exchange network. Less commonly noticed are the constraints upon B's actions, which set the context of action; they are of the special type of selective influence.

Richard McCleery studied the changing basis of power and authority in a prison, relating it to communication patterns. He found that for this relatively stable social system,

...an 'authoritative allocation of values' in that society becomes a matter of the creation and

circulation of definitions rather than a matter of the application of force. While abstract political theory may find the ultimate basis of authority in force, empirical research often finds interaction equated with influence, and the process by which definitions are given equated with power.⁶

The prison was initially authoritarian, with effective control over the inmates in the hands of the custodians rather than administration. By controlling the rules of the game, they were able to operate much in the way of totalitarian leadership.

Uncertainty, even more than exemplary punishment, is a keystone of 'terror' as a technique of government, and it was a major factor in control in the traditional prison." Control over communication produced effects normally associated with direct exercise of executive power.⁷

The captain's office received and transmitted all orders, reports and requests, as well as censoring mail, controlling all movements and contacts in the system. It exercised the power (selective influence) to make and change definitions, thus controlling uncertainty; and it also exercised much of the rest of the influence, which derived from the ability to withhold information. "The techniques of influencing decisions in the prison involved withholding information as well as injecting it into communication channels."⁸

This descriptive model of the relations of influence in a traditional prison was then used as a basis for successfully projecting the effects of change. Briefly,

a liberal administration was able to effect no reforms, even with publication of an explicit code of rules and procedures, until it had successfully taken over and redesigned the communication patterns.

A study of obedience by Stanley Milgram appears to illustrate the predominance of selective influence, where it is perceived to be legitimate.⁹ Milgram investigates the behavior of a naive subject who has been introduced to a conflict: whether and how much to obey the demands of an apparently legitimate authority, thus to inflict pain on another person. Under the pretence of a legitimate scientific experiment at Yale to discover the relation of learning and punishment, the naive subject, upon repeated commands from the experimenter in lab coat, administers what he believes to be electric shocks ranging from 15 to 450 volts. (This belief was reinforced by his receiving an actual 45 volt shock at the beginning). The victim, a "mild-mannered and likable" accountant, pretends to suffer increasingly severe shocks which are administered each time the victim gives an incorrect answer. At 300 volts, he actually pounds or kicks on the wall and thereafter gives no answers (treated as incorrect).

Surveys of anticipated results showed that even the most pessimistic expected no more than 3% of a diverse sample of subjects to obey up to the final 450 volts (the last six increments of 15 volts each were labelled

'Danger: Severe Shock'. Despite this, and despite visible anxiety, laughing fits and hesitations, twenty-six out of forty subjects obeyed all commands to continue to the very end. Only fourteen were 'defiant' subjects, disobeying commands to continue in the range of 300 to 375 volts.

It seems that both kinds of influence are in evidence here. There are two examples of selective influence. Milgram has what McCleery called the power to make definitions; he exercises this in making and changing the rules of the experiment. Then the experimenter, carrying out these rules, has the power of so constraining the possible actions of the subject that at the point of disobedience he has only two choices. (The fourth and strongest command at any point of hesitation is, "You have no other choice, you must go on"). The subject, on the other hand, exercises only influence based upon ordinary information. He is to be paid for his work regardless of completing the experiment, and he achieves no success in attempts to influence the experimenter (Milgram ignores these attempts, which are evident from his few excerpts, in the form of special pleading by the subject on behalf of the victim). The subject's only effective influence is over the victim. It is based on his control over the shock button. He believes no shock to be obviously preferable or valuable to the victim, and he has the influence which comes from the

ability to withhold or administer^{this}/information. The victim appeals to the subject to obey a command which is not immediate in the situation and for many subjects was not operative at all: that is, the selective influence of ordinary morality which constrains one not to inflict pain. The unexpected tendency toward obedience, despite the fact that subjects control the shocks and have the power to disobey without penalty, appears to result from the predominance of selective influence over ordinary influence. Milgram has designed an unusual case where the two seem to be separate but equal and conflicting. The more usual case finds both kinds of influence either widely dispersed or in the hands of the same decision-maker. An individual who threatens with a gun is in the position of making the rules as well as administering them.

If influence can be reduced to information, and social action treated in terms of this notion and its obverse - the reduction of uncertainty - what is then required is to place information and the information network into a social context which has hitherto been referred to as a political space. The minimal network or space is a social action unit.

2.2 THE SOCIAL ACTION UNIT

The social action perspective is an approach to behavior derived from the work of Talcott Parsons; it takes action to consist of "the structures and processes by which human beings form meaningful intentions and, more or less successfully, implement them in concrete situations."¹⁰ The behavior of an actor may be analysed in terms of these abstract constructs, which Parsons called structures or processes. In his view, four of these must be assumed in order that four corresponding functions can be performed.

The abstraction and generality which persisted in the literature on the Parsonian model prevented its application to concrete situations. Aside from its orientation to stability, which was common in early systems models, the attempt to fit it back onto observed behavior raised ambiguities. A single function was performed by no specific set of referents; great difficulty thus arose in attempts to operationalize it, such that as an empirical model its validity could neither be proved nor disproved, and as a descriptive model or scheme the obscurity and lack of referents limited its usefulness.

Some of the difficulty was overcome in successive restatements of the model by Neil Smelser. His work on structural change during the industrial revolution was described in sec. 1.1. The Luddite disturbances were an important factor in that change, and more recently, in a

study of many collective movements, he refined the action model as follows:

For any instance of action we wish to analyse, then, we have to pose four basic questions: What are the values that legitimize this action at the most general level? By what kinds of norms is this action coordinated and kept relatively free from conflict? In what ways is the action structured into roles and organizations? What kinds of situational facilities are available?¹¹

Moreover, he assumed that these components are related hierarchically (Fig. 4) in that order, so that values both constrain and are implemented by norms or rules, and these in turn constrain the interaction structure of rules, which are finally implemented by situational facilities. It was still a deterministic and rather static model which opted for ideational rather than technological determinism. "To put the matter formally: any redefinition of a component of social action makes for a readjustment in those components below it, but not necessarily in those above it."¹²

Fig. 4 The Components of Social Action (Smelser)

There is little provision in the scheme as it exists for the impact of technological, economic or knowledge resource changes to register in the structure of roles or in the normative superstructure. Smelser tended to see the development of movements in terms of either a respecification or a qualitative change within a single component. But the whole strength of the differentiation sequence model was that it accounted for change throughout a concrete action system.

An example may be presented to clarify. Smelser gives an economic example, consisting of the four components as follows:¹³ the value of 'free enterprise' is implemented by conformity with institutional norms such as rules of contract, property, etc. Norms are implemented by the structure of roles which makes up the Business firm itself, and in turn, this component is realized in the available means, such as the accumulation of knowledge, capital, skills, credit, etc. Criticism must be made of the lack of ability of the model to account for the real goals of the firm and for specific exchanges with its environment.

'Free enterprise' is presented as the overriding value to be attained by a firm. In some general sense, a government might pursue policy goals which could be described as free enterprise, but bureaus and firms attempt to realize much more concrete values. Of course, values of many kinds are realized as resources in order to achieve the

output goals of the action unit. Where no rational direction exists, they might become the only goals, but that too requires upward information movement. Daniel Lerner presents this definition:

VALUES ARE DESIRES. What men want is what they value. What they will exert themselves to get is what they value highly in practice, whatever values may be attributed to them in legend.¹⁴

Smelser appears to take on an antique view of values as orientations of the actor to others and to the world, despite, as noted, Parson's view that the action unit forms 'meaningful' intentions to be realized. The problem derives from the influence of Clyde Kluckhohn on the original Parsonian formulation. His work on value-orientations as aspects of a total society's world view was important in anthropology but should not have passed uncritically into a supposedly dynamic model of a modern action unit.

As selective information, value-orientations operate normatively like other perceptual habits which are shared through the whole social system. At a more general social level than that of the action unit, norms 'structure' action because individuals who share them also share the same 'definition of the situation'.¹⁵ In modelling the action unit, we are interested in the particular values to be realized and rules to be followed which are peculiar to the action unit. This is related to the other criticism on the problem of environmental exchanges: after defining values to be pursued, the action unit must realize them,

as well as other resources, in the environment.

In an attempt to construct a more dynamic and operational model of the action unit as an information-processing policy-making system, attention is drawn to an aspect of Smelser's hierarchical arrangement. Despite reservations about the exact meanings to be attached to each component, it will be seen that each level successively constrains the lower by in turn limiting the potential complexity of the decision problem of goal attainment and the range of possible actions which the action unit might then pursue. In each case, selective information is being generated which effectively constrains and specifies action.

With knowledge of its current state and past experience, the action unit isolates its goal values as a desired future state. The market goals of a firm might be prescribed by a parent company or defined by the firm itself, but they are perceived with respect to the environment in terms of the uncertainty and complexity which they represent to the action unit. The initial and most important way that this uncertainty is reduced is by developing the selective information which says what game the action unit is in.

For example, a decision by a firm that its major capacity lies in a specific market imposes the basis for strategic planning. Such a decision, though rarely taken as a single act nor often even explicitly considered,

does carry with it many environmental constraints on operation in a desired market. Together with the initial policy design, these constraints (health standards and legal limitations are examples) make up the selective information by which an action unit initially perceives its task as an area of relevant uncertainty.

If these four components are treated not as abstract functions of an action unit considered in a static sense, but as specific levels of selective information which successively constrain the range of possible action, then it is appropriate to ask what organizational functions actually generated each level of selective information. In sec. 1.4, the basis of a middle range model of a policy-making action unit was presented in terms of three levels of information processing activities. The information to be processed at each level was called policy design information (pdi), policy selection information (psi), and policy operations information (poi). These kinds of information are required, so it was argued, to perform corresponding kinds of policy/^{analysis}or planning functions (following Jantsch and Ozbekhan): (1) normative or policy planning (the 'ought'), (2) strategic planning (the 'will'), and (3) operational planning (the 'can'). The components of Smelser's model reappear as the negative constraints of separate types of selective information, which in a dynamic context are policy outputs of the three information processing levels. That is, SI-1 to SI-4 on Fig. 5 act as constraints on successive policy levels.

Another line of research (in systems engineering) has resulted in the modelling of complex systems where insufficient information is available for control decisions to be taken. Hence, Professor Mesarovic and his colleagues have proposed a hierarchy of decision functions, including the control and coordination by which specialized activities are integrated. Under conditions of uncertainty, a decision problem has three essential aspects: "(i) the selection of strategies to be used in the solution process, (ii) the reduction or elimination of uncertainties, and (iii) the search for a preferable or acceptable course of action under prespecified conditions."¹⁶ In turn, these three layers make up a decision hierarchy which performs the following functions: (1) self-organization, which is a goal-related strategic function; (2) learning or adaptation, by which, as in policy selection, uncertainty is reduced; and (3) selection, by which a course of action (or a control operation) is selected. In terms of policy analysis activities, it seems appropriate to stress the ways by which uncertainty is selectively reduced at each level by particular information processing activities. Figure 5 shows these activities by which various information (I) is processed and uncertainties reduced by policy outputs of selective information (SI).

An action unit is thus modelled as a system which attempts to survive in what is ultimately an uncertain environment by processing and generating information, with the overall object and effect of reducing uncertainty. 'System' refers not to the relatively stable structure of elements whereby a change in one requires adjustment in all, but to a more dynamic notion of functional constructs (rather than entities), which simply convert particular inputs into particular outputs. The action unit is thus an open system composed of three subsystems. Each subsystem or level reduces the range of possible uncertainty with which the action unit might cope by again constraining the

selective information from a higher level in a particular way. If the unit were somewhat passive and unchanging, then SI 1 to 4 would perhaps be adequately described by values, rules, roles and facilities respectively. In a more gesellschaft type of action unit, considerable rational calculation will be involved to produce each of these as a more conscious policy output. In the former case, selective information negatively constrains possible action; in the latter, it positively prescribes it.

The transformational function at each level may be described, beginning at the most simple layer, as follows:

Level 3: Policy Operations At this level of operational planning, one or several problem-solving groups perform specified tasks according to a routinized programme of operations (neither of which is changed at this level). In the example from cryptanalysis: SI-3 refers to a key or code for solving cryptograms which has already been broken; SI-4 refers to the selective demand for resources (in this case, assuming the personnel, experience and other requirements have already been selected from resource markets, SI-4 is the demand for cryptograms; I-4 is then the input of cryptograms); finally the operational group merely applies the code to a selection of cryptograms to yield I-3, the knowledge of secret messages. This simple level of learning-stimulus and programmed response (equivalent in learning complexity to a thermostat) proceeds as if it had certain

knowledge of the environment, and it can do this because actual uncertainty has been reduced to a policy problem which can be acted upon by roles (a set of behavioural expectations) which have already been programmed.

Level 2: Policy Selection- At this level, uncertainties have only been reduced to the point where the rules of the game (by which goals may be attained) are known. Behavioral strategies must be selected which will best realize given goals. These strategies (SI-3), as suggested above, specify a specific organizational configuration to perform the programmed operations: in a passive gemeinschaft action unit it will be a communication structure consisting of an ascribed pattern of roles; in an active gesellschaft unit, a more explicit, adaptive and adjustable communication system may be expected. Risks are undertaken, though they may not always be calculable, on the basis of cost-benefit and other psi (I-3), electing the optimal normative design (SI-2) and breaking it into problems that can be solved by specific problem-solving operational groups.

The great uncertainty which prevails with a normative policy design (SI-2) is significantly reduced by selecting a specific programme on the basis of past experience and rational calculation (psi or I-3). In specifying subproblems in terms of an operational structure of problem-solving groups, a complex organization is merely obeying the economic requirements for an efficient division of labour

and specialization of function. But in the more limited context of individual problem solving, Herbert Simon observed a common and similar process in many subjects which could be simulated artificially. The complexity of a general problem was commonly broken into problems on which known operations could be worked: "Each problem generates sub-problems until we find a subproblem we can solve - for which we already have a program stored in memory."¹⁷

This type of strategic policy output - constrained from level 1 by a normative reduction in uncertainty, but where an interaction structure for operations has to be prescribed - is sometimes referred to as a learning strategy. Norbert Wiener, in a supplement to his early work on cybernetics, gives a dramatic example of the predominance of learning strategy over operations. In a game of combat, the cobra is invariably killed by the mongoose, though the former is by no means inferior in operational powers, such as the speed and deadliness of his strike. Wiener interprets the winner's skill as a capacity for learning:

The mongoose begins with a feint, which provokes the cobra to strike ... we have a rythmical pattern of activity on the part of the two animals.... As it goes on, the feints of the mongoose come earlier and earlier in phase with respect to the darts of the cobra, until finally the mongoose attacks when the cobra is extended and not in a position to move rapidly.... the snake's pattern of action is confined to single darts, each one for itself, while the mongoose's action involves an appreciable, if not very long, segment of the whole past of the fight. To this extent, the mongoose acts like a learning machine....¹⁸

Level 1: Policy Design- Occasionally, the overall tasks or function will change, even for the most passive action unit which undertakes no explicit policy design or selection activities. The generational change of personnel will introduce stress, even where environments are assumed unchanging and internal innovations are stifled. For more dynamic action units, policy design is likely to be a more explicit and frequent activity. Policy-making at this level follows the definition cited from Jantsch in 1.4: "Policies are normative expressions of future states of dynamic systems."⁹ At this level the subjective and almost random uncertainty of the environment is significantly reduced by selecting a problem area and processing such knowledge (I-2) as the current state and internal opportunities of the action unit.

Environmental constraints on policy design (SI--1), including the selective information which feeds back market reactions on current outputs (I-1), condition the possible tasks which a new policy design might specify. But the whole internal information network which makes up the political space of an action unit permits its resources to be deployed around the performance of specified tasks in a problem area. If the example is a subsidiary of some sort with no means to influence the definition of its problem area, then it must be considered part of some more general action unit.

Although great environmental constraints may exist (SI-1), the action unit must be basically responsible for converting them into a problem area; in other words, to develop and employ its own policy design information in converting SI-1 to SI-2, thus specifying an area of relevant uncertainty. In so doing, it also specifies a wider information network of other action units seeking to realize similar or substitute values under similar conditions of uncertainty. Action units in that network are capable of exercising selective influence upon each other (our interpretation of Lowi's policy arena) in a way which is most clearly shown in the example of action units in a field of knowledge. That application may be pursued at length by first enlarging the model of an action unit to include the arena of influence which it shares with other action units.

2.3 THE POLICY ARENA

The political space of an action unit was defined in terms of levels of policy making based on a communication network. Basically, policy is made for the realization of values, and then they are realized by individuals or groups linked together into a communicative interaction structure according to some learning strategy. The action unit enters into exchange relations with its environment when it realizes resources (SI-4 and I-4) and values (SI-1 and I-1). Thus, other action units may exert ordinary influence through

their power to alter or withhold resource supports such as equipment, skills and technology. A number of resource markets are commonly involved, each constrained by laws and structured by some communicative interaction structure. Early in the paper, their influence on a given action unit was described as 'technological imperatives'.

But the action unit sustains selective influence from its environment as well. In the market for the output (I-1) of an action unit, others make policy and take actions which constrain policy designs and possible actions. Even in an example where the action unit has a monopoly in an economic market, buyers and administrative agencies can introduce changes into the market which radically constrain alternatives for the monopolists. The network of action units which can exert selective influence on each other may be called a policy arena.

The policy arena exhibits a structure similar to the lower levels of an action unit. While an arena is organized around a problem area (usually a cluster of social values, such as housing), it has no goal-seeking or policy design facility. Nevertheless, it does have an interaction network which permits communication among related action units. Moreover, this structure (market operations) is always constrained by some normative strategy consisting perhaps only of negative legal constraints, but occasionally a

more positive learning strategy will have evolved behaviorally.

Where a government agency exists to make or administer policy for an arena, the operation of the two-level structure may become more evident and perhaps more efficient. An agency's normal function would be to administer existing legal constraints on the market, but, as in the case of the Atomic Energy Commission or the early CBC, it might be an active participant at the operational level of the arena. Government agencies will undoubtedly exert influence in the resource markets of arena action units as well. These possibilities often overlap for the same agency, thus increasing the instruments at its disposal to effect desired policies with respect to an arena. They do include the possibilities for government policy outputs in each of the four types of arenas derived from Theodore Lowi and described above in sec. 1.3.

If the selective influence, exerted by a government policy agency relevant to the problem area of the arena, were such as to actively design goals and policies for the whole arena, then in effect that agency would replace the output market, and the arena would have to include other agencies with which it competes for funds. This extreme example might be realized in a small totalitarian bureaucracy, but, as noted already, the information costs of processing

Fig. 6 The Policy Arena

and policy making in a synoptic way for total societies makes it unlikely. What we more commonly encounter are a large number of policy arenas, each structured by an information network in which many action units interact in order to realize an adjustable set of social values.

From the point of view of any participating action unit, these values would be perceived as a problem area. To realize them, one must act and interact in a market about which one can have only limited information at a given time. The selective information which can be drawn from various arenas in which one might participate serves to reduce the

potential uncertainty considerably. The information network of the action unit itself is designed to reduce the problem area to a routinized operational level where a virtual state of certainty is assumed. But the market itself is an arena of influence, with an operative but probably less efficient communication network, within which the potential uncertainties of a problem area are selectively reduced.

Information drawn from the policy arena - such as knowledge of the more or less constant market institutions and legal constraints and such information as would yield knowledge and even foreknowledge of the actions of others in the market - bears a selective influence on the action unit. Its uncertainty is reduced by information which in this special instance has a selective influence. One way to re-incorporate the formation of expectations and hence of policy-making into economic theory, wrote Herbert Simon, would be...

by treating information-gathering as one of the processes of production, so to speak, and applying to it the usual rules of marginal analysis. Information, says price theory, should be gathered up to the point where the incremental cost of additional information is equal to the incremental profit that can be earned by having it.²⁰

There are hazards with treating information as a commodity owing to its special properties. For example, patents award the inventor monopoly rights in return for making his information public. But his monopoly is only over an innovation as carefully specified, one which can with ease be

re-specified. To withhold information for personal use, on the other hand, as Kenneth Arrow indicated, can be self-defeating, since selling it once could destroy the property rights (cheap reproduction and distribution) and using it exclusively similarly reveals the information to competitors.²¹ Insofar as it performs a selective function, however, market information is the meta-commodity which circulates, however imperfectly, through any market, reducing uncertainty and constraining policy-making at the highest level.

Noting the 'satisficing' or sub-optimization behavior of policy-makers, who appear to be 'threshold sensitive' when adjusting policies to changed circumstances, Prof. Lamberton forwards the hypothesis that it is information costs which determine such thresholds, over which policy adjustments are contemplated.²² Whether this may be the case, it seems clear that to a decision-making unit, policy information costs are significantly different and lower for internal policy information on the one hand and for external selective information from the market on the other. Costs of information may be assumed even, in a relatively stable situation, over a whole network. Indeed, the abstract and 'perfect' market has been identified as one in which "...all potential bids and offers are known at zero cost to every other person and in which contract enforcement costs are zero."²³ In the real world, transaction costs exist but must be relatively even over a given market. In

terms of the model outlined above and the application to follow, it is important that a level of information costs prevail throughout a given network;²⁴ and for any arena or issue area an action unit contends with an internal network of presumably low costs, with an arena network where costs of selective information may be quite high, and with networks in resource markets where information may be less critical but may also be high in cost.

It has been argued that action units, in the arena defined about a given policy issue or set of social values, interact and exert influence and selective influence on each other through an information network. The literature dealing with this type of approach is not plentiful, but it is also not limited to economics. The role of policy design, of government agencies and of influence has been ignored by economists. A host of possible strategies exist which action units may adopt with respect to other action units. They range on a continuum from policies by which an action unit controls its environment to policies which permit control by the environment. The sociologists Thompson and McEwen list four points: (1) competition, implying much independence and assuming much information; (2) bargaining, the "negotiation of an agreement for the exchange of goods or services between organizations" but not assuming government as a third party; (3) cooptation, by which outside elements are adopted

into the leadership of the action unit (as in the case where, in need of credit, a firm or university names a bank director to its Board of Directors); and (4) coalition, by which action units combine for a specified common purpose (such as a joint defence contract).²⁵ If one considers the uncertainty problems facing policy-makers, it will be observed that these four strategies are different information inputs. Where they involve others in the same policy arena, they are inputs of selective information (and hence of selective influence), by which the action unit effectively reduces the uncertainty in realizing its goals by entering into relations with others in the arena. As Thompson and McEwen suggest, where specific operational groups are responsible for supplying a resource not drawn from the policy arena but critical at the moment (such as credit), the particular problem of that group tends to become the dominant goal of the action unit, and in a sense the single group behaviorally designs policy for the whole. Policies to permit various other kinds of influence may include monopoly (to wipe out influence and selective information by occupying the whole arena), vertical integration (to wipe out influence from resource markets), licensing, subsidiaries, technology transfer agreements and contracting out. For such strategies, knowledge of legal constraints and government policies is essential, and the problem of how much environmental influence to permit is a function of the degree of

uncertainty prevailing in the arena or appropriate resource market.

On the basis of fairly extensive study of the canning industry and the National Farmers' Union in Britain, Emery and Trist identified four types of environments (or arenas), based on the type of uncertainty prevailing there.²⁶ Type I, the 'placid randomized environment', is characterized by relatively unchanging values distributed randomly. The firm is assumed to be perfectly informed (by experience) of this environment, and policy here corresponds to that of the operational level discussed in sec. 2.2. Type II, the 'placid clustered environment' is similar except that values are clustered, requiring some strategic development in terms of a desired future state of the organization. The imperfections in its environment create uncertainties requiring learning and information-gathering activities and risk-taking in the form of technical or bureaucratic management. Type III, the 'disturbed reactive environment' assumes not only the clustering of values, but their pursuit by other organizations capable of equivalent learning. In addition to the notion of a strategic future state, this environment calls for planned sequences of learning tactics which Emery and Trist call management "operations". Finally, Type IV environments are called 'turbulent fields'. This condition arises from all firms pursuing operations in competition to such an extent or in such complex areas that

their actions alter and enlarge the areas of relevant uncertainty in the arena. Redefinitions of uncertainty are fundamental policy design decisions, amounting to adjusted self-images and redefinitions of the arena.

This typology emphasizes the factor of uncertainty in policy decisions and the corresponding kinds of influence and selective influence that must be tolerated in order for that uncertainty to be reduced. Examples which illustrate aspects of the model of a policy arena in the cited literature deal largely with economic markets (ignoring policy agencies and influence relations). Because this model has emphasized the information network as the basic structure of political spaces, it is appropriate to turn for illustration to the problem of policy for fields of knowledge.

CHAPTER 3

EXPLORATORY APPLICATIONS IN THE FIELDS OF KNOWLEDGE

The struggle for policy analysis was traced in the opening chapters to an early and more illustrious breach in the political thought of the last century. It derived, so it was argued, from a difference in view on an issue that remains unresolved: that is, the role of information in policy making.

For the model developed in the last chapter, the role of information was particularly critical for policy designing within networks where uncertainty is great. For example, in the turbulent arenas described by Emery and Trist, actions undertaken not only augment the uncertainty in the arena, but they may create turbulent conditions by actually altering the area of relevant uncertainty itself. Action units which commonly must contend with such turbulence are to be found throughout the so-called 'information industry'.

The production of knowledge in any form has always been a source of change. New techniques and innovations of all kinds may carry great implications for change wherever they are introduced. This is to be expected since the information carried by an innovation solves some problem, perhaps the intended one, but by so doing, it may alter the parameters of further problem-solving in that field. New knowledge would not be useful in an activity did it not perform this function of generating uncertainty. The information

industry, consisting of institutions and organizations for the production of innovations, has no monopoly on novelty, though it does specialize in it; but the information carried by innovation here is usually in the more familiar sense of new knowledge.

Where action units exist solely to generate innovations and knowledge, one must expect them to create turbulence almost as a measure of success. For such cases, policy design becomes a matter of survival, a continuous process of redefining areas of relevant uncertainty. Yet no action units have demanded independence and lack of constraints more loudly or more successfully than those which make up what Michael Polanyi pointedly called 'the republic' of science.¹ But the information sector of advanced industrial societies has increased in economic, military and social importance such that few governments have failed to attempt to design policies for science and technology. Many of the first agencies were set up during World War I. Without recounting the case histories that abound, it shall have surprised no one by now that the struggle for policy analysis broke out first in the house of science.

In the section that follows, a method is discussed for applying the model to a field of recorded knowledge. The concept of a field is of course problematic, and the method is uniquely devised to render a field of knowledge in

terms of the structure of its communication network. Three dimensions of such networks which may be empirically and independently derived are: the authors in a field, its channels of exchange (journals), and its subject literature (a file of documents). The model anticipates particular learning strategies, such as working paradigms and methods unique to the field.

On the basis of well-documented network structures, the following sections consider questions of usefulness and hypotheses arising from the rest of the model. In 3.2, the use of the networks as a basis for organization of policy making for science is taken up, along with the prospects which arise from the model for a new research undertaking on international science. A number of propositions of interest to prescriptive policy making, the sociology of science and intellectual history are considered in 3.3 and 3.4. The potential of the model is developed
/for handling key variables of change in limited middle-range arenas. Available studies are cited in support of certain propositions. A concluding section reconsiders the model in the light of the contending views described in the opening chapter.

3.1 APPLICATION OF THE MODEL TO A SCIENTIFIC FIELD

Fields of science provide excellent employment for a change model which presents action as oriented to the reduction of uncertainty. Science, or rather scientists in social contexts such as research labs, define uncertainty and attempt to reduce it by the generation and organization of knowledge. The consumers of this output are other scientists; thus, exchange networks come to be defined within which one exerts influence^{by} (and pays deference to) the production of knowledge.

This approach is consistent with that of the sociological study of science, where norms and roles are stressed. Aside from the study of particular disciplines and work situations, sociologists tend to look at all of science as a social system of exchange. Constrained by the general norms of science (Norman Storer² identifies six such norms: objectivity and generalization, organized skepticism and communality, emotional neutrality and disinterestedness), and more actively by the requirements of scientific method, scientists are presented as motivated toward the priority of scientific discovery. Robert Merton's view, which became the initial point of departure for this particular literature within the general sociology of knowledge, was that a scientist is oriented toward contributing new knowledge in return

for the esteem and reward of recognition by his peers for the priority of his discovery.³ In terms of an exchange network of information, this means that he must formally present his findings into some communication network of his peers, and in turn receive their recognition. The extent of recognition may be indicated by the extent to which others use his findings in their research.

This of course would be most difficult to document in most areas of technology, as the experience of Project Hindsight shows.⁴ Recognition and use of most technical innovations were found to rely basically on interaction structures inside an action unit; only infrequently did patenting or other documentation come to be used. Thus, very intensive and often subjective research, limited to a few situations, would be required to describe the information networks involved in a given problem area of technology. (A possible exception to this is explored below in 3.2.)

If, on the other hand, we consider scientific fields where research findings are documented, then the problem of studying many such networks becomes a feasible research undertaking. To be sure, scientists rely heavily on informal communication, especially in the interaction structures which their own labs or university departments permit. And the informal circulation of findings - of reports and preprints of articles which may not appear for months and even years because of peer-group reviewing procedures and the inefficiency

of journals - this informal circulation is part of the way a network of scientists must work. Conferences are held and papers delivered which may not be published; but it remains that in fields where a cumulation of knowledge has built up - including social sciences - that cumulation could only be achieved by reliance on formal channels for circulating printed documentation.

This is not to deny that in applied areas of knowledge cumulation required other means of storage and transmission. In fields of medical surgery, one suspects, journals may be only supplementary to the slow build-up of tacit skills, the use of video recording tape, computer storage of case files and of course the communication of skills and knowledge by teaching and demonstration. A university faculty after all is an information resource quite as much as its library.

But the formal and predominant channel for scientific fields has been printed documentation, even where alternate channels would be faster and more convenient. One suspects this is due to the requirement for recognition of priority, if not property, in one's discoveries and contributions. Information even in science (perhaps especially in science) is not free and cannot move in an unrestricted way.

Fig. 7 The Research Front in a Field of Knowledge

In terms of the model developed in Chapter 2, one can classify and locate on a diagram those variables which are anticipated by literatures about science and by the model itself. Fig. 7 depicts the whole arena of influence which makes up a field of knowledge. Each level is structured by one or more empirically discoverable information networks. (These are the 'a' functions: 1-a, 2-a, 3-a and 4-a.)

Level 1: Science in General: At the most general level where all of scientific knowledge is represented (1-a), it is not assumed that all scientific fields are linked into a single exchange system such that findings in one area are utilized in other areas where they are applicable. The classical idea would be that science forms a single body of knowledge (1-a), constrained or acquired only by reference to a strategy of 'scientific method' (1-b). In the more passive approach of the sociology of science, 1-b would be a strategy consisting of the norms of science. This classical view is an assumption that could be demonstrated on the model if it were the case. We know little of how in practice to define and investigate a working strategy for the whole of science, or even of how to discover if one exists. Of the several senses in which Thomas Kuhn discusses his concept of a 'paradigm',⁵ the metaphysical sense of a generalized world-view, if it existed and were shared by all scientists, would be depicted on the model in 1-b. But any assumption of a shared working model or heuristic paradigm about how the world works (e.g. a

Newtonian world view) would be unwarranted. If the classical view of a single body of systematic scientific knowledge has validity, then that recorded knowledge should turn out to be linked into an exchange system or network. In other words, however tenuous the linkages might be, in the long run any single document would have some relevance to all documents.

But such is not the case. Instead, an investigation of documents in 1-a leads to the discovery that, as one might expect, discrete fields of knowledge exist in highly integrated networks which are loosely joined or unrelated with each other. However, there still must be a sense in which scientific knowledge is distinguished from that which is 'unscientific' (i.e. a value judgement). 'Scientific methods' and norms perhaps have little selective influence on day-to-day research. But where boundary disputes come up, where for whatever reasons it is decided that a contribution or theory is repugnant to science, these most general norms are called into play (objectivity and reliability of data, along with replicability of experiments, are the major normative rules). They are used much as a national ideology might be called up to declare that some members are enemies of the people. The actual reasons for exclusion on such principles are likely to have a more worldly quality down in the operation of the arena itself, where working paradigms perhaps do exist as part of an established learning strategy which is threatened by the innovation to be excluded.

Many cases may be cited where this abstract sense of science has been called up to serve an ideological function. Thus are summarily dismissed the work of both genius and crank alike from the corpus of scientific knowledge. Subsequent reappearances of the former have done nothing to alter the history of this practice, which is, after all, the only rule of law in Polanyi's republic. The experience of Immanuel Velikovsky and Marshal McLuhan appears to be typical of such cases.

Velikovsky, trained in Europe as a psychiatrist, but also a serious student of law and archeology, contributed a theory in astronomy based on highly speculative analysis of myths and artefacts from the past. The scientific community, led by an astronomer who had been approached by Velikovsky for help in testing the theory, prevented its publication in all science journals and denounced its subsequent success in popular journals and eventual publication by MacMillan. Under pressure, MacMillan's fired their editor and switched publication to Doubleday. Worlds in Collision may have been the work of a crank; it did enjoy popular success, but its interest lies in the use of level 1-b sanctions. The eminent astronomer who, while he had not read Velikovsky's manuscript, did lead the attack on it, described his reaction in this way: "If Dr. Velikovsky is right, the rest of us are crazy."⁶ The theory was never criticized as a contribution to a field of research, despite its astounding success in

predicting evidence that eventually turned up in the Mars probe and elsewhere.

McLuhan shares much with Velikovsky with respect to the exclusion of his work by communities of social scientists. Trained in literary criticism, he turned from early and conventional analysis of poetic symbols to symbols in popular culture and eventually to a theory about the structure of a medium. The popular applications of this theory in many directions involved him in the subject matter of all social and psychological disciplines. But citing none of the relevant literatures and, perhaps more important, observing none of the paradigms in circulation or the accepted ways of developing evidence, he continued to write popular works which display considerable critical insight into many aspects of society. His basic theory concerned a sense-perceptual notion of a world view and the neo-Marxian hypothesis that this was directly conditioned by the technology of communication. It was never actually published and did not reach the social psychologists and other researchers who might have translated it into the type of propositions which could be empirically investigated. Similar hypotheses and paradigms from anthropology and linguistics had already been revised and developed into substantial contributions to the sociology of knowledge.

The list of such cases is not short nor limited to obscure boundary disputes. Theodore Gordon⁷ documents similar

cases, Nobel prize winners and cranks, where norms for all of science, rather than intellectual arguments specific to a research area, were used ideologically to ban material from the realm of science proper.

All this leads to the suspicion that there are norms of science in general, though they function perhaps rarely and ideologically. The sociologists investigating these norms have interpreted them as value-orientations after a research tradition in cultural anthropology. That is to say, in the study of culture areas for the purpose not only of recording ethnographies but of studying the diffusion of innovations and other problems of cultural contact, the group of anthropologists represented especially by Clyde and Florence Kluckhohn devised methods of classifying distinctive values along several profiles, each representing a continuum of value-orientations which would be critical for comparing any culture.⁸ Examples are the orientations toward time (past, present or future oriented) or whether they are oriented toward self or others. Now these profiles attempted to model groups of values critical to a whole culture; but a similar approach in the sociology of science resulted in half a dozen such orientations, or as they call them, norms, which distinguish the area of 'scientific culture' from other ways of knowing or acquiring knowledge.

Norman Storer's work reviewed the contributions to

a study of scientific norms, especially from Bernard Barber and Robert Merton. He was at pains to distinguish norms as "standards of behavior" from values as end-states or desirable goals.⁹ This distinction is equivalent to that made in chapter 2.2 where values and norms were described as separate levels of selective information resulting from policy-making decisions. In considering science in general, it is undesirable to assume any specific overriding values or goals, although this model anticipates an overall implicit function of the reduction of uncertainty. The only point to be made here is a classificatory one: that if these norms are operative as they appear to be, or if some other set of norms is operative, including for example more explicit rules about procedures and methods in science, then they would turn up on this model as a system in 1-b, selectively constraining 1-a as to the inclusion of new knowledge and supporting the existing distribution of knowledge.

Scientific knowledge, as formally represented in published documents, is distributed by fields in level 1-a. Administratively and institutionally, these fields were traditionally assumed to be distributed along the boundaries of a few 'disciplines' of science. This view places emphasis on the information processes - textbooks and teaching - by which what is already known in science comes to be acquired by potential researchers. Even where recognition is made of new fields established by inter-disciplinary research, the

view is conservative and lacks a suitable concept about change. The sociology of scientific norms has done nothing to alter this state of affairs. For example, Professor John Ziman interprets the set of norms from Barber and Merton as consequences of the implicit need for a consensus about scientific knowledge.¹⁰ Thus, the value-orientations toward the body of science, to encourage consensus, would require objectivity and generalization; toward relations with other scientists: organized skepticism and communality; and toward the appropriate psychological state for research: emotional neutrality and disinterestedness. In this way, findings cumulate and universal consensus about the body of knowledge is established; Professor Ziman calls this consensus 'public knowledge'.

There appear to be two problems with this view, and a single remedy. The emphasis on consensus and pedagogy reverses the dynamic quality of change and new knowledge from research which was actually fundamental to Merton's view of priority and recognition. Secondly, the notion of a consensual body of knowledge, relatively inert and subdivided into institutional chunks fit for teaching, is not by itself a useful or operational concept. However, by adopting a complementary approach, emphasizing the dynamic networks which integrate these literatures into operational research fields, that is, by turning from the mélange of consuming

'publics' to the active research fronts, both the problem of equilibrium and subjective categorization of public knowledge fall away.

A field of scientific knowledge may be defined as a file or set of documents which are related bibliographically. M. M. Kessler provided a qualitative indicator of the extent of such relations as follows:

- (a) A single item of reference used by two papers is called one unit of coupling between them.
- (b) A number of papers constitute a related group, G_A , if each member of the group has at least one coupling unit to a given test paper P_0 .
- (c) The coupling strength between P_0 and any member of G_A is measured by the number of coupling units
- (n) between them.¹¹

Thus, an entire subject file can be reconstructed from any one of its member documents. In principle, without any analytic knowledge of a field, its file of subject literature can be derived by selecting a single document and noting its references and the cited literature contained in each of them. As this process continues through the file, the geometrical progression which one would expect if, say, all of science were a single subject and were cited at random, rather quickly curtails with a great deal of overlapping or coupling. Nevertheless, the clerical problem would be immense were it not for the ease of punching the references found in each document onto a machine-readable card for that document. In this way, a matrix can be derived, mapping document-to-document relations and showing the clustering or areas of high coupling strength which make up sub-fields or research fronts.

Another aid of much importance is the data already collected in various forms in the Science Citation Index.¹² One of several uses of the Index is in the construction of a file of documents; but rather than working backward in time through the references on each document, the Index permits working forward in time, listing all the documents which in the period cite the initial document. It is useful to apply 'reference' to an information transfer which requires going to the past and transferring forward, and to apply 'citation' to a transfer forward from the given time to some future document.

In describing a method for applying level 1 of the model to the norms and literature of science in general, it may be appropriate to conclude with a note of interpretation. The clustering of subject literatures into fields has a time component by which new documents cite very selectively over the past literature of the field. Moreover, attention is drawn not just to the file of documents but to the way by which new documents continually re-specify the subject field as a research area. Despite some individual idiosyncracies in citing behavior, the occasional review article and negative citation (i.e. citing a bit of knowledge one thinks wrong), the citation is uniformly demanded to pay deference to a source where information generated from that source is both relevant and essential to problem-solving in the paper at hand. Of course studies of informal communication among scientists

indicate a small percentage are initially informed of work crucial to their own by journal articles.¹³ But even if informal channels precede journal publication, this formal recognition is only established by the latter system. Indeed, informal channels are found to re-enforce the small formal networks which exist on research fronts. The grouping of documents thus represents not just a working organization of the body of scientific knowledge, but one of the working scientists as well. Producing scientists are distributed among research fronts, and their output selectively cites from their whole field in 1-a, reinterpreting that field in particular ways which can be investigated at level 2. By successively perceiving the past of their field in certain ways, they select not merely documents from it, but they are continually defining and redefining the problem area, or area of uncertainty relevant to them, which it represents. That is to say, the subject literature may be understood to refer to an area of uncertainty quite as much as to a body of knowledge.

Level 2: The Research Front: The document coupling by references in 1-a indicates that networks of documents exist, and it suggests that those who produce those documents are similarly integrated. These working scientists are located in various labs or research settings structured as in level 3; but they are linked together into research fronts. These fronts are distributed over the history of their subject

literatures on level 1-a; but any given or current research front can be singled out for analysis. The model anticipates that the research front will be composed of action units (level 3) which have been linked together by channels of communication to form a particular arena of influence or network. If they are so integrated, the model further anticipates that all action units in the research front, aside from their unique research policies, would share, on 2-b, a common learning strategy of some sort.

The notion of a heuristic paradigm has been elusive in its many interpretations. Margaret Masterman, as noted above, found Thomas Kuhn's usage to consist of twenty-three distinctive though not usually conflicting senses. It seems clear that the non-conflicting senses are really the result of using the same term for functions that occur at different levels. Particularly confusing is application of the same term to 1-b (a strategy of organizing all of science according to some world view), to 2-b (a particular way of perceiving the problem area of the field), to 1-c (a research strategy), and even to critical inputs from level 4 (a key technology implying new organization and new research strategy). All of these ideas are important and so, worth keeping distinct from each other. Nevertheless, research fronts, early in their interaction, rarely would be expected to have developed a full-blown theory or exacting research methodology. Thus, the term research paradigm might well be reserved for an early stage of the learning strategy of a given research front. It

remains to be demonstrated whether a distinctive learning strategy exists for each research front, but if it does, the model anticipates that it will function on 2-b as a learning strategy.

Levels 2 and 3 define a concrete organizational network; and level 2-a refers to the communication channels (journals or other formal media such as reports) which circulate findings among members of that network. By their competitive and cooperative interaction in the network, the action units evolve a learning strategy which is not only a way of perceiving the field, but of perceiving the uncertainty which it represents as a problem area. The learning strategy - a research paradigm, or, at a later stage, a methodology or a fully developed theory - is a normal strategy for reducing that uncertainty. The research front collectively specifies the uncertainty relevant to it by the particular way it cites from the past literature of the field. Members of the front are thus constrained in their separate research designs by a group learning strategy which disposes them to approach the problem area in a particular way.

The network structure (2-a) of the research front may be approached in two ways:

(1) The concrete referent for 2-a is that set of journals which transfers the research information from one part of the research front to the other. This set of journals will differ from that which carried the whole range of field documents

in 1-a.. Again, the Science Citation Index will yield information on journals that tend to cite each other. The separate journal used more or less exclusively by a given research front may be critical to its initial establishment as a distinct field.

(2) The authors of papers in the research front, though they are located in labs, etc., on 3-a, are the agents who are linked together by virtue of their separate output being used by other members of the network. Thus, the members who actually make up 3-a may best be determined by analysing 2-a as a network of authors (in addition to a set of journals).

This analysis is similar to the clustering of documents in 1-a, except it has the virtue of not being bound by a time dimension. A document at time t_1 can reference many past documents, but it can be cited by no future ones. Two documents cannot cite each other; a third is required to establish the coupling. But on a research front, where all authors continue to live over the period of interest, we may look at those authors from whatever discipline who cite each other, regardless of the work in question. Without the time constraint, the idea of the network as an exchange system becomes even more realistic. Multiple authorship does not disturb the network; though junior authors on a given title might not yet be able to close the exchange coupling. Other scientists may read work from the research front with interest; still others may reference it without their own work contributing in any formal way to the research front in question; finally, a third group

(possibly from the past of the field) may be cited by members but not themselves cite in return; all of these are of particular interest for other purposes, but those who exchange information by citing each other define a research front which is of great interest for policy making.

Levels 3 and 4: Action Units and Resource Markets:

The referents for levels 3 and 4 are now evident; they do not differ from the description in chapter 2. Fig. 7 indicates three basic kinds of action unit in a field of knowledge. A single scientist working in an independent lab might decide more or less on his own what problem area he wants to work on. If one or more research fronts exist, he will either initiate or be drawn into a research front. If one doesn't exist or is incomplete or unacceptable, action units will evolve a paradigm through which they see reality; this in turn will exert selective influence back on the way individual research policy is designed.

Additional constraints would certainly be imposed on lab policy in the case where the organizational setting is an industrial firm; similarly for government mission or contract labs. These considerations may increase the selective influence on basic policy decisions such as selection of the problem area. Moreover, the information output of the action unit into exchange with the rest of the research front can be seriously hampered by secrecy constraints on the contract lab or withholding for patenting purposes by the commercial lab.

A large lab may of course simultaneously operate in several research fronts.

Within these constraints, action units design research strategies which again reduce uncertainty in ^{the} problem area by breaking it up into operational problems for which procedures exist or can be invented. Level 3-a refers also to many support persons and others who are not producing work in the network in question. They can, however, exert great influence on the direction of lab policy and even of the network.

Resource markets are particular sources of change in any field, operating in this application much as described in Chapter 2. The movement of scientists and other resource personnel within the research front and from outside may yet be the most effective means of innovation and communication. Equipment and funding, in addition to skills, have been singled out as the kind of resources most likely to cause or require innovation in a field of knowledge. Institutional constraints within such markets may also be expected to have indirect impact.

Finally, turning to level 1 again, one or more agencies of public policy will be able to influence the field of knowledge as indicated. Such an agency would of course be part of other wholly administrative arenas in which it competes for funds. It may input information from the whole body of science, but it cannot constrain science in a direct way. Where it sets up labs and requires secrecy, as in the U.S.

Manhattan District for atomic weapons production, it may have the effect of creating its own network or arena of knowledge apart from the rest of science. The major instrument of its influence, aside from contract research without secrecy constraints, is the capacity to influence the resource markets - particularly the specific channeling of funds through education policies, the provision of skills through specific researches, the development and transfer of new technology and equipment, and legal constraints on resource markets (such as easing tax applications for new research). Such agencies, particularly for funding, commonly staff their bureaus and review boards with members of past successful research fronts.

3.2 USE OF THE APPLICATION IN GENERATING THREE BASIC KINDS OF POLICY-RELEVANT INFORMATION

The discussion in 3.1 makes it evident that various kinds of citation tracing can be used to objectively identify and define structurally the actual fields of scientific knowledge, the networks of authors who have created the field literatures, and the 'cutting edge' of current activity: the research fronts. Each of these could be immensely informative in the making of policy for science.

Organization of Policy for Scientific Fields: Policy analysis for government science policy has been marred not only by political disputes over the efficacy of government or any outside intervention, but related to this dispute are at least two assumptions often made in science policy which are by no

means warranted.

On one side of the dispute, scientists are part of professional associations established many decades ago when subjects of study encouraged such general disciplinary lines as biology, physics and chemistry. Science as an attempt to understand nature solidified institutionally around subject matters that refused to remain stable. Disdain in the 'republic' of science for outside intervention tended to brand research as either 'pure' or 'applied', by which is meant respectively: undirected science for the sake of knowledge and science directed to specific ends. These distinctions tended to be maintained in the organization of policy agencies which fund research; allocations are made in these categories, with leading scientists reviewing proposals from their disciplinary peers. Reports from agencies, such as the U.S. National Science Foundation and others, present their data on allocations based on these categories. Even more active policy-making agencies and government labs tend to maintain these distinctions. The situation is somewhat equivalent to the traditional organization of a foreign office, with desks assigned to geographical areas of the world. When Britain's navy was the major instrument of her foreign policy, it would seem no doubt perfectly logical to have a Middle East desk, a China desk and so forth. Fleets after all were limited geographically and technically in their deployment. Superimposed on this type of foreign office structure we now find task groups organized somewhat tentatively about temporary missions

or problem areas.

On the other side of the dispute over intervention and science policy, there is the facile assumption that a causal relation exists between expenditures on research and development and levels of economic growth. New scientific knowledge is purportedly turned to various applications, giving rise to inventions which, when developed as a new product or process, will then be a useful innovation which, in turn, when transferred to other areas, will result in many innovations, all contributing to higher productivity and greater output. This assumption appears in a variety of literature. For example, the reports of the Senate of Canada Special Committee on Science Policy, which advocate new government machinery and increased funds for science policy, present many such R & D/GNP comparisons both within Canada and among advanced countries.¹⁴ Though they wisely encourage an information policy for the foreign and domestic transfers of science, skills, patents and innovations, the relation of these to specific economic objectives will clearly be relative to particular industrial and market situations.¹⁵ Even if models existed for such comprehensive policy-making, the problems of calculation would be insurmountable. Moreover, it is historically not the case that there is a line of development from scientific discovery to innovation. Scientists have always worked back to theory from development experience. Steam engines were first built and improved, finally becoming efficient at an economic level, and had much of their immense

economic and social impact before theories were developed to explain thermodynamics. Project Hindsight in the U.S. Department of Defense traced the development of twenty items of defence technology which had been developed there since the War. One of the tasks was to discover the role which their basic science funding had had on desired technical innovations. These two conclusions are among those offered by the project director:

For relatively well established technologies, a constant rate of growth in relevant knowledge results in a decreasing rate of growth in technological capability.

The rate of growth of knowledge is directly related to the relative level of informal person-to-person communications in relevant technical areas.¹⁶

Both of these assumptions - the traditional disciplines and the R & D/GNP relationship - are, interestingly enough, officially shared by both sides in the science policy dispute. Scientists claim economic payoffs to justify funds; agencies follow suit in their budget competition with other agencies. The organizational inertia of both is also distributed along traditional disciplinary lines.

A single public policy could not be contemplated for the whole of science, since the costs of the necessary information would be prohibitive and since action units make the bulk of science policy themselves. Nevertheless, over time, action units do build up subject literatures wherein the subject may be inferred from bibliographic coupling. Moreover, the current research front(s) in a field are similarly discoverable. It

is plausible that realistic levels of basic policy information for science could be based on the objective discovery of what current fields of science actually are. A government agency could, as a minimal effort towards policy analysis, orient its policy-making activities toward actual fields of science.

This type of reduction of complexity by a policy agency exhibits at least a preliminary effort in the same type of learning strategy as that described for all action units. An agency set up to make policy for a sector of the information industry might be expected to reduce its problem area (in this case - science) into operational sub-problems. It can do this on the basis of policy relevant information drawn from the body of science itself.

There are of course parallel implications for educational policy, and especially at the level of university administration.

Policy Information in National Science Policies:

Robert Gilpin has drawn attention to three types of strategy for national science policy:¹⁷ (1) a strategy of national independence, whereby the great powers presume to lead on all fronts of science and technology; (2) a strategy of specialization, whereby selected fronts become the subject of national development; and (3) a strategy of imitation and absorption, whereby selected foreign science and technology is imported by means of licensing, patents, multinational corporations and the trade in high level skills. He concerned

himself with developments toward an international economy based on the imperatives of new technologies, and with the possibility that even the superpowers could not afford a 'national' policy on all fronts. Policies of specialization and absorption need not be alternative as Gilpin supposed, nor limited to problems of advanced technology. But they are worth considering in the light of international science and policy in advanced and developing countries.

The citation tracing techniques for discovering and analysing networks of authors and working fields of science can readily be adapted to this range of problems. It would seem to be a logical progression from the idea of orienting science policy toward subject literatures. Knowledge of the extent of cross-national links in subject literatures and research fronts should be of particular interest to countries following policies of specialization and absorption in science. For example, if it were known that a country of strong but not universal productivity of papers in science had either inadvertently or by design developed or wished to develop specific research fronts, policy makers would be well informed if they looked at (1) the extent to which the network is within the country; and then with respect to peripheral citations, (2) the extent to which that research front or network is cited by foreign authors, and (3) the extent to which the network imports science by citing foreign authors.

Moreover, upon receiving funding requests, a policy agency should inform itself of the research front represented

by the proposal, in the context of other decisions it has made. This need not only enhance an established elite of scientists, for even an unpublished researcher will have written a thesis which, though not cited by a network, would have established past research interests; and the proposal would reference key sources on which information could readily be generated about the relative development of any research front.

This type of information would be particularly critical in developing countries such as India, where limited science resources are disposed in conjunction with specific economic and technical goals. A particular problem, then, is the extent to which scientists are contributing to research fronts addressing development problems or to scientific 'fashions' initiated in advanced countries but irrelevant to development.

In fact, the USSR has recently become very interested in this kind of approach. V. V. Nalimov headed a twelve-man team which analysed aspects of the international flow of information in selected scientific fields loosely defined by subject journals.¹⁸ They found 40 to 60% of the information flow provided by English language countries, 20% by the USSR, 5 to 10% by German language groups and 5% by Japanese. The two major countries contributing this literature were found to be engaged in excessively closed information systems, drawing on their own stock of scientific capital by self-citation as follows: U.S. and Britain: 68 to 88%; USSR: 37 to 65%; West Germany: 29 to 46%; and France: 6 to 35%. Mr. Beck draws

attention to the role of translation activities in encouraging the use of foreign science, as reported in a study at Syracuse University for the National Science Foundation.¹⁹ Citing this and other studies, Beck reports that translated Russian journals are cited as frequently as German journals (which are not translated) and that in a selected field of Russian achievement, two of their journals were third and fourth in numbers of citations among all journals. These studies are of course only preliminary, indicating the usefulness of the approach. The Science Citation Index, covering only 700 journals, is inadequate for analysis of science in developing and other foreign countries. OECD and UNESCO have clear responsibilities to undertake more serious studies in the field.

Policy for Research Fronts: A third kind of policy information readily generated from the model follows directly from the other two but is less general in scope. It derives from the ability to define research fronts without subjectively analysing the content of the subject literatures. Though the approach anticipates some of the following discussion in 3.3, it is the case that non-coercive policy can usefully be made directly with respect to a research front.

Certain features of the research front are salient. A few individuals, usually in primary contact with each other, define the problem area in a new way. Informal communication is important to them, including reports and the circulation of unpublished papers, or papers to be read at a future conference.

The development of their work, its publication and their contact influence with others is hindered (1) by the need for some explicit discussion of their evolving research paradigm (this assumes that one function of the paradigm is to ease communication), and (2) by not being in contact with others who have been using or citing their early work.

Now, a policy agency, by monitoring reports, theses and conference papers, and especially searching out closely linked clusters of exchange citations within current subject literatures (these would be expected to exhibit peculiar bibliographic coupling to the past literature of the field), can inform itself of research fronts at an early stage of their development. D. J. de Solla Price has made use of several field literatures to discover their research fronts; he made these observations:

Although most papers produced in the year contain a near-average number of bibliographic references, half of these are references to about half of all the papers that have been published in previous years. The other half of the references tie these new papers to a quite small group of earlier ones, and generate a rather tight pattern of multiple relationships. Since only a small part of the earlier literature is knitted together by the new year's crop of papers, we may look upon this small part as a sort of growing tip or epidermal layer, an active research front.²⁰

These research fronts account for about seven new papers per year for every 100 previously published in the field. Such a network (he elsewhere uses the term "invisible college"²¹) cites only part of the whole field in a particular selective way, distinguishing it from 'taxonomic' contributions which

periodically review a field and tend to cite over the whole range of its literature.

A policy agency can exercise influence in the development of research fronts in at least two ways. (They can also create them by transferring or developing new technology such as instrumentation, but that is part of another strategy).

(1) An agency can serve as a clearing house for information exchange (there is evidence for this approach), and (2) it can observe the peripheral citations to the research front from the outside, that is, citations by peripheral authors whose work is not in turn cited by members of the front for one reason or another. By placing peripheral researchers into contact with the front, policy agencies might speed up its development.

Though the analysis of peripheral citations did not inform their selection of member scientists, the interesting case where this has been tried is the Information Exchange Group (IEG) set up by the U.S. National Institutes of Health.²² Any communication - paper, note, criticism or list of references - sent by a member to IEG is immediately duplicated and distributed without censorship to all members. These are dated private communications which may be quoted, so that priority of discovery is protected; and there is the strong incentive to contribute an idea because of the speedy and relevant feedback. However, anyone working in ^{the} interdisciplinary group of fields in any country may become a

member or recommend another. For this reason it does not function as the network of an actual research front, but it undoubtedly would have the effect of encouraging the development of active fronts if the potential for them is there. In reviewing the first four years of operation, its Chairman acknowledged (with some pride) that "IEG No. 1 includes every active worker in its designated field in this country and abroad."²³ Apparently, 90% of the 'important' world literature in the field was submitted to them (some 300 papers) and 90% of that consisted of preprints: "The judgement of one's peers serves as a major deterrent to the submission of marginal papers of the potboiler variety."²⁴ The immediate transformation of the group into a prestige academy for screening journal papers may be the result of the wrong approach to membership; clearly it precluded its development as an active research front.

Informal communication "of the potboiler variety" is exactly what links a research front, particularly when it is new. Nevertheless, as Mr. Alan Moore points out, this experiment, which by 1965 had seven IEG's, reduces international constraints on the movement of scientific information. Twenty-seven countries were represented, with 38% of members outside the U.S.²⁵ It would seem that the device could be used to more effectiveness if it operated on a stronger base of information about operating networks.

3.3 SELECTED PROPOSITIONS FOR WHICH SOME EVIDENCE EXISTS

Deriving a model of social change is different from entertaining a theory of change. A strength of the model presented here is that it simultaneously accommodates several variables, some of which have been found to be critical in different case studies and change theories. A theory relates variables in particular ways which can in principle be discredited. Theories of change have been at the center of conflict in social thought from the beginning, and these conflicts have rarely been resolved since the theories have not been comparable and have often been presented as mutually exclusive.

The sociology of knowledge has largely accumulated as a result of the application of various social change theories. To speak generally, and without citing from a vast literature, there are really two views, one Marxian and the other idealistic. Marx located the determinants of any system of values and norms in those social relations associated with a given technology of production. Derivatives of this view include variants of technological determinism of cultural variables, and as in the Smelser sequence in 1.1, the view that a significant alteration of a social structure must result in altered values and structures. In Whorfian linguistics, a derivative of this view explains a cultural 'world view' in terms of categories of its language considered as a technical instrument. On the side of idealism, there is even less

consistency. Some have assumed legal or constitutional determinism, and a current derivative is the view that institutions such as property rights or the ability to legally form corporations are at the basis of economic and social change. Kuhn uses different versions of the 'paradigm' concept to reverse Marx and all his derivatives (though one version of paradigm really upholds the 'law of the instrument' which is strictly Marxian).

The model of a field of knowledge is no cure for this conflict, but it appears to have properties which might permit some of the essential elements in the conflict to be demonstrated and even tested for particular cases. An empirical definition of 'research paradigm' remains of course elusory. For the purpose of evidence, secondary data must be used. Several citation tracings now exist along with many sociological case studies of labs. Some of the tracings were designed for purposes which makes them irrelevant to the model, but a few appear to be very useful.

The citation analysis used here was developed by William Goffman to illustrate his 'epidemic' theory of the diffusion of information.²⁶ He was able to work from a complete bibliographic file - the library collection of Hans Selye containing all documents relating to mast cell research, from the discovery of mast cells by Ehrlich in 1877 until 1963.

(Proposition 1) Structural change among action units is expected to result in a significant change in the fields of science to which they contribute. Another way of stating this hypothesis would be that development of a research front should occasion a significant new direction in the subject literature. The independent variable is derived from an exchange network of authors as described. The dependent variable is indicated by a shift in bibliographic coupling among documents in the whole field. This results because (a) the research front is contributing a new surface of papers to the field (i.e. grouped in a specific way and not linked to the rest of the field in the same way as before), and (b) because the research front cites from the past literature of the field in a particular new way (i.e. a non random pattern different from that which existed).

Working from Garfield's data in the 1961 Science Citation Index for all references in that year to works published from 1862 onward, D. J. Price plotted the increasing incidence of source references over the years. Then selecting an obscure discovery in 1904 as the beginning of a discrete subject literature, he plotted on a matrix the bibliographic coupling of references, thus yielding cluster patterns of those parts of the past of the field that were, with each new group of publications, considered relevant.²⁷ This descriptive work for the history of ideas is also interesting as an example of the dependent variable for the above hypothesis. But Price did not follow his analysis with the successive exchange net-

works of authors who separately referred to each other's works. The hypothesis would project that exchange groups would also signal distinctive usages of the past. Lacking a particular sociological interest, M.M. Kessler's analysis of references in a year of the Physical Review (ref. 11) also looked only at the coupling of documents.

Following Goffman's method of tracing the diffusion of ideas in terms of a model for disease spread wherein authors are infectives, Joseph Donohue did an analysis of author networks over the history of information sciences.²⁸ He found that the epidemic curves for numbers of authors and productivity corresponded well with anticipated patterns of bibliographic coupling. This would encourage acceptance of the proposition, but the causal strength of the relation remains in question; or at least awaits the introduction of additional variables.

(Proposition 2) If the adoption of a resource technology by an action unit requires structural change, then it is anticipated that its research front will change significantly and that a structural change will occur in the subject literature.

One of the features of Goffman's epidemic model is its ease of correlation with other events over the history of the subject literature. Goffman assumed that the authors of the 2,282 documents in the complete file of a subject literature indexed from the Hans Selye collection in Montreal were each potential infectives. By plotting their entry and withdrawal and their interconnections, outbreaks or epidemics of

research were evident at various times.

When, in 1953, into the resource market for equipment to conduct mast cell research the electron microscope was introduced, a rather serious restructuring of laboratory work had to take place. New expertise was necessary, but when it was acquired, research could not proceed as before. We may assume that infected labs were restructured. Goffman traced the citations dating from that time and found evidence that a distinctive new exchange network (or as he terms it, 'epidemic outbreak') started to evolve in the years following 1953. The subject literature expanded greatly and readjusted itself to the new research front. Goffman's analysis was tentative, based on the short span of time since 1953, but he concluded:

Thus, it is predicted that the use of the electron microscope will become 'epidemic' in mast cell research and that this epidemic will reach its peak in 1978, which is precisely when mast cell research as a whole will attain a maximum.²⁹

On the problem of structural change in the action unit resulting from a policy to adopt a new technology, some sociological case studies are instructive. Gerald Swatez provides a rare analysis of the social structure in a 'big science' lab.³⁰ The problem-solving nature of organizations is most evident in this study of the Lawrence radiation lab. Everything is organized around the major technologies - the particle accelerator and bubble chamber - which not only created new research networks but came to define the field of particle physics. Few major technologies would require such adjustments. For example, extensive computation facilities exist but have

probably not structurally altered the kinds of work done there nor the organization of the work. But the accelerator is such that because of its cost, large research teams must schedule their time with it and effect a "complex division of labour around large instrument systems."³¹ These teams of about 200 have evolved around the research work and influence of a few key scientists in the lab; as a result, graduate training is somewhat specialized and authorship often extends to many names. The evidence is clear that policy designs in the lab and even the field methodology have changed significantly under the use of these technologies.

Another kind of resource input may also be used to demonstrate the second proposition, insofar as the action unit and its policy are considered. It was argued from the sociology of organizations that the implicit policy followed by an action unit may often be a function merely of the behavioral competition for influence among operational groups. In other words, that an action unit might be more oriented to a particular resource market because of, say, the need for credit, and the overall goals become defined by these limited operational goals. Warren Bennis has in fact described two MIT research groups, one oriented almost completely to a funding market, the other producing knowledge in a field of development science.³² The latter, because of liberal constraints on the funds it had, was able to design policy toward a problem area in its field, to actively participate in a research front.

But the other lab was dominated by the need to justify its existence to a granting agency every few months. The implication would seem to be that any resource input can carry implications which, if absorbed, could require a fundamental reorientation of the action unit, even at the normative policy level.

(Proposition 3) Normative constraints on the policy design of an action unit will have the effect of removing it from its research front if the constraints are sufficient to alter the interaction structure. In other words, it is expected that when policy making in a lab is constrained by selective influence from an arena other than its research front (such as its parent industrial organization or government mission agency) sufficiently to alter the ^{role pattern of} behavioral expectations of its members, then it will tend to cease participating in the network of its research front, and engage in other arenas.

There is considerable sociological research to support this hypothesis, but as yet the citation data is lacking which could make the proposition conclusive. What is involved here is the tendency to replace the pluralist 'republic' of science by other organizations. The case of secrecy in government research demonstrates the proposition well. Not only is a contract set up which constrains policy design in the action unit by specifying the research area, but an additional institutional or legal constraint is added which can only have the result of altering the research front by withholding the

output of new knowledge from it. The role-model of a single contract researcher in this case must change to the professional-client model of, say, a consultant. If a whole lab is involved, or set up expressly for mission research with secrecy constraints (e.g.ⁱⁿ the Manhattan District), then the hierarchy of the organization itself replaces the field of knowledge. The pull of the organization of the 'big science' lab and its master/apprentice role models may have a similar detrimental effect on 'cosmopolitanism' in science. That is, the lab itself may become so interdisciplinary, the papers excessively multi-authored, and the local rewards so predominant that, quite without secrecy constraints, the big science lab could form an IEG and research front entirely by itself.

The opportunity to discuss the interpretation of data with fellow workers and the need both to explain ongoing analysis to graduate students and to help them with their problems of interpretation are important occasions for collective scientific creativity.

This 'communal data analysis' leads almost imperceptibly to more formal 'publication' of findings. In this group, publication may first occur at the group's regular Monday evening seminar at the group leader's home, which is modelled on a regular seminar Ernest Lawrence held for some years, and is considered by the group to be very valuable for early 'semi-formal' airing of ideas.³³

Organizational rewards such as advancement and local recognition in industrial labs can quickly subvert the more ephemeral peer recognition of cosmopolitan science. Thus, Simon Marcson reports:

The laboratory attempts to pull the recruit into its value system and redirect his research interests. It is concerned about the recruit's attitudes towards the industrial laboratory, but tends to view the cause of them as someone else's fault.³⁴

The industrial lab may certainly become an alternate organiza-

tional system which implements specific goals using somewhat unique facilities and particularly unique role organizational and career-oriented norms. The particular derivative here is the goal of advancing knowledge and particularly techniques toward the goal of innovation which is within the commercial competence of the company. Such goals are rewarded extrinsically to science by non-scientists in terms of professional and career rewards. Marcson distinguished four career patterns which display varying degrees or forms of acculturation into the industrial organization. They are: (1) the research career, whereby the recruit 'internalizes' the organizational norms of the lab and after a few years takes on the lab's definition of research, which is within the constraints of the projected production innovations of the company; and three types of administrative careers: (2) where he takes on administrative duties, joins societies, but within a reward system of the employer-employee role type; (3) where he chooses the lucrative administrative career on its own merits; and (4) where he chooses such a career because of lack of research ability. In his book³⁵ Marcson sets down the corresponding status hierarchy of the industrial lab as follows: (a) top laboratory management, (b) research direction, (c) research supervision, (d) professional research staff, and (e) technician.

With completely alternate arenas to occupy the scientist, industrial and mission labs can obviously constrain the action unit by normative influence (as shown on level 3 of Fig. 7) to such an extent that the pattern of behavioral ex-

pectations in the lab would be fundamentally reoriented.

The evidence indicates that work in research fronts would then cease, to be replaced by participation in other areas. Citation data could show this more conclusively if it were available.

This is not to argue that a scientist cannot participate in other arenas or even several research fronts, but it does assert that participation in any given research front is dependent upon a supporting social context - a role structure. It may also be an indication that norms of science do exist, at least to the extent a shift in value orientations is implied when a scientist is withdrawn from science into non-science arenas. National and non-science organizational norms can cut across research fronts and fields of science:

Recently it came to light that scientific papers are 'commodities' and as such require a State Department license for export, along with such other items on the United States munitions list as submarines and tanks.³⁶

Along with this harsh statement it may be kept in mind that Linus Pauling was prevented from giving a scientific paper in Paris in the early nineteen fifties by the denial of his passport.

3.4 CONCLUSION

The basic purpose of devising a model of this type, one which accommodates a number of variables and sources of policy making, was not to demonstrate that a synoptic model can describe the findings of diverse literatures. It was simply to accomplish two things: (1) to model change in the actual social contexts as may be discovered from different case studies; and (2) to include in the model those mechanisms which might realistically be anticipated for the planning of change.

Reviewing the discussion of alternative approaches to policy analysis in the opening chapter and the models which evolved in each of them, it may be observed that the action model presented here has at the least a greater capacity to classify and organize relevant materials from organization and management theory, decision theory, case studies of policy making and change, and aspects of systems theory and policy sciences. But the model is really specialized and strictly delimited in any particular application. For given a particular policy problem, a relatively large number of important variables are brought to bear on it in a highly structured way. Given a sufficient amount of empirical indication for these variables, contending theories of change might be submitted to testing for different types of cases.

The discussion of descriptive models of policy making emphasized both the information needs of policy makers in highly rationalized policy making and the social costs of change when policy is not made and information in the change process

is generated out of conflict. The incremental approach emphasized the economic cost of widespread or synoptic planning of change. Taking these together, a strong argument is made against centralized planning of change. The action model in chapter 2 is favourably disposed to meet this argument, since it pictures a middle-range social context of policy making in the hands of several action units. In this approach, it is clear that government planning is most effective by indirectly influencing the resource markets of policy action units, particularly for fields of science.

One behavioral approach made fairly extensive use of the concept of subjectively derived policy arenas called into existence by different types of policy issues. By transferring this concept of influence relations to the basis of a concrete information network, much more exacting use is made of it. The use of correlation of decision variables and impact variables was interpreted in 1.3 as a potentially useful device for feedback information on the effects of policy decisions. In the model additional decision and impact variables have been set out, have been more differentiated, and of course placed into a more realistic social and economic context.

But the usefulness of any model in policy analysis must ultimately lie with its ability to generate new and relevant information for policy makers, especially at the government level. The techniques relied upon most heavily in the science policy application involved the use of citation tracing. The founder of the Science Citation Index, Eugene Garfield, wrote

with reference to an early study by J.H. Westbrook, that:

Westbrook...has justifiably used citations as a means of determining the sources of activity in particular research fields, and citation indexing clearly and demonstrably has proven to be an excellent means of 'defining' a field.³⁷

With actual referents for the history of a field and also for the networks of authors at any research front, the virtue of organizing science policy based on this kind of information should be obvious. And it is consistent with the consideration of immense information costs for large scale centralized planning. Policies for support can realistically be made for limited arenas such as the research front.

Since the process of transmitting ideas, as in the case of an infectious disease, is not a single process within a population but a collection of interacting processes within sub-populations, it would seem that the notion of an all-encompassing information retrieval system spanning the totality of knowledge should be replaced by the notion of small dynamic interrelated systems that appear when needed and disappear when not needed.³⁸

Additional policy information may be drawn from the relations of variables on the model. Of course, as a working model, it makes information about a policy process available. But information in the process must be drawn from analysis of variables and relations on the model. Knowledge of subject literatures and research fronts are examples. And section 3.2 also investigated three propositions which could provide additional policy information in given arenas of science. A specialized data base could not be developed for this application, so propositions were selected where secondary evidence seemed strong.

The possibility of separately investigating networks of authors on research fronts and subject literatures seems to have been established in the sources. On this basis, the results of change in additional variables such as use of a new technology - electron microscope, accelerator, bubble chamber - or particular funding inputs can be traced in research fronts and literature productivity. A minimal nucleus of authors and journals is probably required for establishment of a distinctive research front, along with a common research paradigm. Investigation of the latter would at this time require subjective analysis of the content of the literature.

The influence of industrial or other constraints seems also to establish the possibility for normative sources of change. But the social function of science and the necessity for informed policy with respect to it remain the most fundamental of modern political problems. A crystallographer and political activist, J.D. Bernal, wrote in 1938:

Science puts into our hands the means of satisfying our material needs. It gives us also the ideas which will enable us to understand, to co-ordinate, and to satisfy our needs in the social sphere. Beyond this science has something as important though less definite to offer: a reasonable hope in the unexplored possibilities of the future, an inspiration which is slowly but surely becoming the dominant driving force of modern thought and action.³⁹

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CHAPTER 2: An Information Model of Policy Making

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⁹Storer, op. cit., p. 76.

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¹¹M.M. Kessler, "Comparison of the Results of Bibliographic Coupling and Analytic Subject Indexing", American Documentation, 16:3 (July, 1965), p. 203. Kessler had earlier applied this method to thirty-six volumes of the Physical Review: "Bibliographic Coupling Between Scientific Papers", ibid., (January, 1963), p. 10.

¹²Science Citation Index, issued quarterly and cumulated annually by Institute for Scientific Information, Philadelphia.

¹³Bently Glass, Sharon Norwood, "How Scientists Actually Learn of Work Important to Them", International Conference on Scientific Information, Preprints, Vol. 1, (Washington: NAS-NRC, 1958), p. 186. They report only 22% thus informed from regular journal scanning and 8.4% from a journal subscription. Also in ibid., Herbert Menzel, "Planned and Unplanned Scientific Communication", p. 189; and M. Halbert, Russell Ackoff, "An Operations Research Study of the Dissemination of Scientific Information", p. 87.

¹⁴Report of the Senate Special Committee on Science Policy, A Science Policy for Canada, Vol. 1, (Ottawa: Queen's Printer, 1970), pp. 119-124, and Vol. 2, (Ottawa: Information Canada, 1972), p. 488.

¹⁵B.R. Williams, "Industrial Research and Economic Growth in Australia", Fisher Lecture, (Adelaide: Griffin Press; 1962), p. 15.

¹⁶Ienson, op. cit., pp. 53, 54.

¹⁷Robert Gilpin, "Technological Strategies and National Purpose", Science, 169 (July, 1970), p. 441.

¹⁸V. V. Nalimov, Z. M. Mul'chenko, Naukometriia (Moscow: Nauka, 1969), reported by Leonard Beck, "Key Issues in Soviet Information", Journal of the American Society for Information Science, (March/April, 1971), pp. 82, 83.

¹⁹Syracuse University Research Institute, A Study of the Frequency with which Russian, French and German Scientific Articles are Cited in Selected American Scientific Journals, (Syracuse, 1966), (PB-170 620).

²⁰D.J. de Solla Price, "Networks of Scientific Papers", Science, (July, 1965), p. 512.

²¹D.J. de Solla Price, Little Science, Big Science, (New York: Columbia University Press, 1963), chapter 3. He does not interpret the invisible college in terms of influence: "They are just the hierarchical elite resulting from an expectable inequality, and numbering about the square root of the total population of people in that area...", Price, "Some

Remarks on Elitism in Information and the Invisible College Phenomenon in Science", Journal of the American Society for Information Science, (March/April, 1971), p. 75.

²²David E. Green, "An Experiment in Communication: The Information Exchange Group", Science, 143(Jan. 24, 1964), pp. 308, 309; and Green, "Information Exchange Group No. 1", Science, 148 (June 18, 1965), p. 1543.

²³Ibid., (1965), p. 1543.

²⁴Ibid., p. 1543.

²⁵C. Alan Moore, "Preprints. An Old Information Device with a New Outlook", Journal of Chemical Documentation, 5:3 (August, 1965), p. 127.

²⁶William Goffman, "Mathematical Approach to the Spread of Mast Cell Research", Nature, 212:5061 (Oct. 29, 1966), p. 449. Also Goffman, Newill, "Generalization of Epidemic Theory: An Application to the Transmission of Ideas", Nature, 204:4953 (Oct. 17, 1964), p. 225.

²⁷D.J. Price, op. cit., (July, 1965), Fig. 6, p. 514.

²⁸Joseph Donohue, A Method for the Analysis of a Subject Literature, Ph.D. Dissertation, School of Library and Information Science, Case Western Reserve University, (Cleveland, 1970), pp. 60-64.

²⁹Goffman, op. cit., (1966), p. 451.

³⁰Gerald M. Swatez, "The Social Organization of a University Laboratory", Minerva, 3:1 (January, 1970), p. 36.

³¹Ibid., p. 40.

³²Warren Bennis, "The Effect on Academic Goods of their Market", American Journal of Sociology, 62:1 (July, 1956), p. 28, reprinted in Maurer, op. cit., p. 293.

³³Swatez, op. cit., p. 54.

³⁴Simon Marcson, "Role Adaptation of Scientists in Industrial Research", IRE: Transactions on Engineering Management, EM-7, (1960), p. 164.

³⁵Ibid., p. 30.

³⁶Walter Hirsch, Scientists in American Society, (New York: Random, 1968), p. 130.

³⁷Eugene Garfield, "Citation Indexes in Sociological and Historical Research", American Documentation, (October, 1963), p. 290.

³⁸Goffman, Newill, op. cit., p. 228.

³⁹J.D. Bernal, The Social Function of Science, (Cambridge: MIT Press, 1967) (first published in 1939), p. 408.

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