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With rising concern for environmental and natural resource problems over the past decade, considerable effort has been devoted to methodologies for environmental impact assessment and integrated development planning. While some superficially new approaches have appeared (e.g., simulation, cross impacts analysis) for handling larger problems with more interrelated factors, the tendency has been to cling very tenaciously to a basic paradigm or world view concerning the dilution of impacts over space and time and between major subsystems (e.g., ecological, economic). Most often this world view is either not recognized at all, or is buried in technical jargon so as to appear unimportant. One is often reminded of the children's story about why ostriches bury their heads in the sand.

The intent of this paper is to critically examine the "dilution of impacts" paradigm. I first attempt to define it more clearly by reference to an alternative viewpoint. Then some examples are presented to suggest that it is becoming an increasingly dangerous and incorrect way to look at the world. I next examine some general mechanisms in modern society that make the paradigm invalid; these mechanisms suggest new directions to look in planning and impact assessment studies.

The "Dilution of Impacts" Paradigm

Systems analysts have been especially fond of telling decision makers about the need to carefully define and bound problems. It is in setting the boundaries that the "dilution of impacts" paradigm becomes critically important; the boundaries must be defined in three basic dimensions:

(1) space - how far away will the impacts reach

(2) time - how long will the impacts last

(3) across subsystems - how will the impacts spread from component to component.

The usual assumption is shown in Figure 1A: we expect the greatest impacts "nearby", with decreasing effects as we move away from the location or abstract decision point. Harmful physical effects (pollutants) are assumed to diffuse in space, damages are assumed to repair themselves over time, economic perturbations are assumed to be damped in a complex network of economic transactions, and so forth.

An alternative world view is shown in Figure 1B. In this view, impacts and problems are not related in any simple way to the location of the development. We would obviously not take this view seriously in dealing with most physical problems (though some pollutants can be concentrated to dangerous levels by biological and physical mechanisms far from their source), but it is not clear that the physical analogy holds in dealing with other subsystems. We might argue (and examples will be presented later) that economic impacts in particular need bear no obvious relation to the initial investment, within broad geograpical and temporal limits.

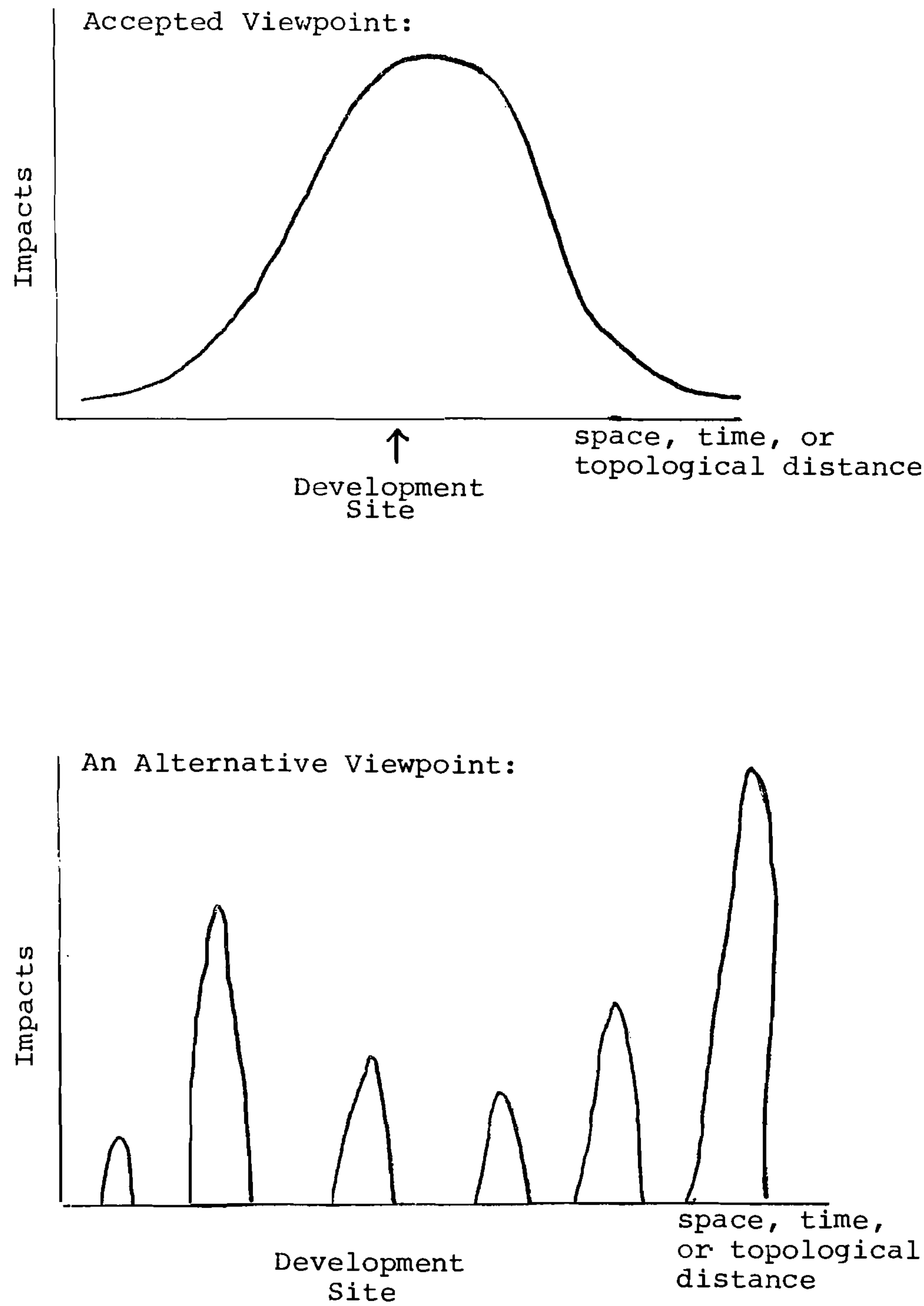


Figure 1. Alternative paradigms for the distribution of development impacts.

It is obvious why the viewpoint of Figure 1A has developed and been found acceptable. Until very recently, physical and economic isolation has been great enough to prevent strong crossimpacts. Ecological and economic systems have had strong mechanisms to buffer change. Also, many scientists would argue that a world structured as in Figure 1B should be essentially chaotic, with large and unpredictable changes occurring in all subsystems at apparently random times.

The dilution of impacts world view is apparent in many tools and associated terminology currently popular in resource planning. The most obvious example is benefit-cost analysis, which calls for a careful accounting of "primary" and "secondary" (or "direct" and "indirect") benefits and costs, and the use of smooth discounting functions. In practical applications, "secondary" is usually equated with "less important" or "less certain to occur". Benefit-cost analyses often make use of the results of another common tool, input-output analysis. The multipliers from this analysis are supposed to capture overall increases in economic activity induced by investment decisions; it is usually assumed that the spatial distribution of the induced activity is diffused or unimportant, and that the time transition of increase will be smooth and controlled.

It is a standard joke that the way to recognize a planner is to look for crayon (or felt pen) marks on his hands. Development plans are always accompanied by a profusion of maps; recognizing that rectangular maps introduce arbitrary boundaries, many planners prefer to delimit problems by natural units such as watersheds. The current height of these infantile games is the elaborate technology available for producing overlay transparency maps for showing how different land use attributes impinge on one another.

Spatial divisions of political jurisdiction and responsibility (in the Western countries at least) have helped to encourage the development of the dilution of impacts paradigm. Existing patterns of jurisdiction have arisen for perfectly good reasons related to provision of public services (transportation, law enforcement, etc.). However, political boundaries are often used to excuse very narrow planning viewpoints; the attitude commonly is: "Yes, I see that impacts may occur over there, but that is outside the boundary of my government's responsibility; let's concentrate on our own problems first".

## A Few Counterexamples

It is somewhat difficult to find examples of how well the usual paradigm works in practice, since most evaluation studies begin with the assumption that the spatial and temporal framework was properly defined in the first place - impact patterns as in Figure 1B may have gone unrecognized in the past, simply because no one has looked for them. However, glaring examples are beginning to appear with increasing regularity.

The United States recently invested millions of dollars on environmental impact studies for the Alaska Oil Pipeline. A small army of researchers and consulting firms made very detailed studies along the pipeline route, and these studies prompted several engineering changes and safeguard measures.

The pipeline will be buried along much of its route, and will be high above the ground in some places; indeed, the local environmental impacts are almost certain to be small. However, little attention was paid to impacts that the large influx of construction workers (10000 at present) will cause. These impacts are not likely to occur along the construction route, but rather around Alaska's population centers and transportation routes to the south. The city of Fairbanks will be hit especially hard; to accomodate workers on leave from the construction areas, considerable housing development will likely occur, and some use will have to be found for this development after the pipeline is completed. Outside the cities, recreation areas (especially for hunting and fishing) that are already crowded are likely to see considerable additional pressure. With a bit of foresight, many of these problems might be handled quite well - but the Alaskan government now considers itself in a crisis situation, and will almost certainly make a series of blunders.

Canada has a similar example with the James Bay Hydroelectric Development. This development involves an enormous area in the northern quarter of Quebec. Environmental impact studies (complicated by institutional problems between the federal and Quebec governments) have proceeded in the usual way, with emphasis on resources in, around, and downstream from the hydroelectric dam sites. There is a pretense of broad, systems thinking about the problem - studies are being conducted on issues like climatic change (the dams will add huge areas of water surface) and the welfare of local Indian populations. However, a key factor has been largely neglected: road access will be provided to the area, and the influx of recreational use may be very large. Our calculations (Walters, 1974) indicate that fish and wildlife losses (recreational harvesting, etc) well away from the dam sites may be ten to twenty times greater than the direct losses due to flooding and downstream damages. Again, with a little foresight this problem could be avoided, controlled, or even turned into a socioeconomic advantage.

The recent dramatic increases in fertilizers and food prices in many parts of the world were preceded by a seemingly insignificant event, the collapse of the peruvian anchovetta fishery. This fishery was the largest single contributor to world ocean catches, and it had been on the verge of over-exploitation for several years. The collapse was caused by an oceanographic condition known as "El Nino", involving intrusion of warm water into the cold, productive upwelling system off the Peru coast. The El Nino occurs about once every decade, and it has two major effects on the anchovetta: reproduction fails, and the fish are forced near to shore where they are more vulnerable to fishing. It happens that the catch is used largely for industrial reduction; anchovetta can be turned into very high quality fertilizer. Between 1965 and 1972, the fishery apparently provided 5-10% of the world's supply of quality fertilizer, and the loss of this supply appears to have triggered many of the problems that housewives face today. It is likely that the collapse could have been prevented by using lower exploitation rates prior to 1972; this recommendation was made repeatedly, but was ignored by the Peruvian government.

Underlying Mechanisms

These examples suggest that two obvious factors which we have been able to ignore in the past are becoming critical determinants of development impact patterns: transportation and economic interdependence. Both have their major influences on the "secondary" rather than "primary" benefits and costs of development.

We usually think of modern transportation systems as a mechanism for dispersing people and the assorted problems they cause. Clearly we need to consider the reverse process as well; resource developments that permit or induce population redistribution can cause highly undesirable concentrations of human activity.

Increasing economic interdependence over large areas is a less obvious and more disturbing factor. In part this interdependence is related to transportation systems, but in general it appears to be a by-product of increasing technological efficiency: as we strive for efficiency in the production of critical goods (such as fertilizer and food), we seem to depend more and more on specialized inputs that cannot be readily substituted. There is a basic principle in ecology that appears to apply in economics as well: increased net production or output can be obtained only at the price of specialization and simplification.

While it is apparent that modern technology can cause shifts in the spatial and inter-subsystem distribution of impacts, it is not clear that we should also expect changes in the time distribution of impacts. In other words, should we be watching for mechanisms by which potential impacts might be "stored" such that they surface suddenly and unexpectedly in the future? In part this question has been addressed by Holling (1973) in his resilience work. He argues that some actions and management patterns may trigger unforeseen (and unmeasured) ecological changes that lead to contraction of stability boundaries; sudden and unexpected changes in system behavior may occur when the boundaries are crossed. For example, stability of a forest insect pest system may depend on spatial heterogeneity of the forest; pesticide spraying may permit or trigger a progressive loss of spatial heterogeneity until an explosive and destructive insect outbreak becomes inevitable.

Consider another (purely hypothetical) example of the time-distribution problem. Suppose we are trying to predict the impacts of a hydroelectric dam in Western North America on salmon populations downstream. The salmon require clean gravel beds for spawning. Silt and other pollutants accumulate in such gravel beds, and it may be that periodic high water flows are necessary to clear the gravel. By stabilizing water flows, the dam may trigger a slow process of material accumulation and deterioration that may take many years to make itself felt. It is not likely that the deterioration would be monitored or noticed until too late.

Economic systems also appear to have mechanisms that can lead to sudden impacts after a considerable time lag. One way to view the recent western ethic of economic growth is as a mechanism to defer impacts into the future. We recently developed a demographic-economic growth-environmental impacts model for the small alpine valley of Obergurgl in Austria (Himomawa,1974). The village and the alpine valley surrounding it form a nicely closed physical and demographic system (no immigration is permitted). Tourism is the main industry, and the village has grown rapidly for the last two decades. Almost every young man builds or inherits a small hotel, and saves money for building investment by a combination of tourist service and construction employment. However, safe land for building is quite limited, and environmental degradation is becoming serious -- within two or three decades the hotel construction will have to stop. This will trigger a wave of emigration of young people from the village, with attendant social problems, that will continue for at least a decade due to the population age structure. Economic growth temporarily hides the demographic problems, just as insecticide spraying hides the changing pattern of spatial heterogeneity in Holling's forest insect example.

Suggestions

This paper has been prompted by a fear that the profusion of environmental planning procedures (see Munn, 1975) that have appeared in recent years may be leading to an entrenched set of formalisms for looking in the wrong places more efficiently . Environmental planning seems well on the way to becoming a structured discipline like macroeconomics, whose spectacular failures to predict the events of recent years (witness the energy crisis) may stem from a similar myopia about modern systems. The macroeconomists seem determined to cling to descriptions of the world based on traditional indicators (GNP,etc.); environmental planning might make a comparable mistake by clinging to the dilution of impacts paradigm.

As a first step, there is a critical need for objective documentation of more examples of development impacts. One might well argue that my examples are rare exceptions and that we simply do not hear about the vast majority of successful development programs that do not result in any major surprises. This may well be true, but some comparative studies might help us sort out a methodology for recognizing the pathological cases, before they begin to cause trouble.

It is not really a major conceptual step to move beyond the map-making, spatially restricted thinking that characterizes most current environmental planning. The same methodologies and ways of thinking that we now devote to the development of tedious lists of impacts and indicators can be fruitfully redirected, simply by paying more attention to mechanisms that may result in redistribution of impacts in space and time. Also we can pay more attention to the obvious fact that development programs involve and induce many inputs and outputs, other than physical facilities and pollutants.

Certainly there are difficulties, particularly in relation to the diffusion of economic impacts. But simplistic, first order environmental planning should not be excused simply because economic interrelationships are poorly understood. As an initial step, I suggest that it is particularly important to discard the primitive notion that costs and benefits can be meaningfully divided into "primary" and "secondary" categories. There is no reason that we cannot deal with complex economic patterns just as we deal with complex ecological ones.

The variety of procedures that now exist in environmental planning, ranging from the formulation of checklists to elaborate cross impact matrices and simulation models, all have the same goal: to help structure and improve the way we ask questions. Yet most of these procedures ask the analyst to look directly at the <u>things</u> (subsystems, indicators) which might be affected; the analyst is supposed to implicitly take account of the <u>processes</u> involved. Mathematical modelling and simulation techniques (see for example Walters, 1974) demand more deliberate consideration of processes and mechanisms, and it has been my experience that modelling exercises always turn up a variety of impacts and problems that have been overlooked in applying the simpler procedures.

Unfortunately, formal modelling exercises require a variety of resources that are not always available; also they seldom produce products that are of quantitative predictive value, and by concentrating on quantifiable relationships they often lead to elegant but trivial analyses of very narrow subproblems (water pollution models are an especially good example of this difficulty). However, there are at least two model building tricks that might be of quite general applicability when trying to deal with situations where the spatial and temporal impact pattern is not clear:

(1) the "looking outward" approach to variable identification.

(2) "input-process" impact tables.

Both of these tricks are nothing more than formalisms to help structure the way questions are asked.

"Looking Outward" approach to variable identification

This approach was developed by my modelling group at the University of British Columbia, through various attempts to coerce traditional, discipline-oriented scientists of Environment Canada away from reductionist ways of thinking. Typically in model building (and impact assessment) exercies, each disciplinarian is asked to devise lists of variables and relationships needed to describe the dynamics of the subsystem that is his speciality. His natural tendency then is to come up with a list that reflects current scientific interest within the discipline; this list is usually unnecessarily complex, and often has little relevance to the development problem at hand.

In the "looking outward" approach, we simply turn this question around. Instead of asking "What is important to describe subsystem x ?", we ask "What do you need to know about subsystem y in order to predict how your subsystem x will respond?" . That is, we ask the disciplinarian to look outward at the kinds of inputs which affect his subsystem.

After iteratively going through this questioning process several times for every subsystem, we can present each disciplinarian with a critical set of variables whose dynamics he must describe before we can generate any picture of overall system responses. Also by asking him to identify the inputs to his subsystem, we in effect ask him to think more precisely and broadly about how the subsystem works. Of course, the subsystem modelling process is also much simplified when the desired outputs are precisely known.

"Input-Process" Impact Tables

This is a variant of the cross-impacts or action-impacts matrices that are commonly used in environmental assessment. The idea is to list a series of inputs (proposed development actions, materials involved in development, pollutants released into the environment, etc.) as the rows of the table, and a series of important processes as the columns of the table. The columns might be for example:

| | |
|---|---|
| transportation<br>substitution of inputs<br>plant siting<br>effluent release | Economic Processes |
| migration<br>choice of recreational sites<br>demographic (birth-death) | Social Processes |
| material transport<br>mass balance relations | Physical Processes |
| dispersal<br>competition<br>predation | Ecological Processes |

Then for each input-process combination in the table, we ask two questions:

(1) Will the input directly affect the process in relation to at least one subunit (economic sector, social group, physical area, or material, type of organism, etc.)?

(2) If so, what spatial and temporal consequences can be expected, for each subunit that is affected?

Thus the input-process questioning tends to focus the analyst's attention on mechanisms that might produce unexpected impacts. Once the table has been developed (and it is usually not even necessary to write down any answers for the two questions above), it is easy to move on to a more specific table where particular impacts or indicator changes are identified in relation to inputs.

## Conclusions

This paper has tried to critically examine one aspect of environmental planning, the problem of identifying development impacts. Current approaches to this problem appear to be inadequate; I have tried to suggest some mechanisms that should be considered and some approaches that might prove helpful. It is easy to find much at fault when looking back at any relatively new area of study like environmental planning; the trick is to learn something from the mistakes.

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