# Asimov's Psychohistory: Vision of the Future or Present Reality?

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ABSTRACT. The science fiction writer Isaac Asimov based his *Foundation* trilogy on the development of the science of psychohistory in the far distant future. Psychohistory permitted prediction of wars, revolution, religious development, and the emergence and fall of a wide range of social, cultural, and economic groupings. Psychohistory used a statistical approach to predict the responses of very large numbers of people to social and economic stimuli, and was unsuitable for small groups or individuals. However, the futurist Alvin Toffler suggests that former large groupings of people are splintering into countless small, temporary, single-issue groupings. In addition, Toffler suggests that a knowledge-based approach, rather than statistical analysis, is the route to understanding changing social and economic conditions.

Natural resource issues can lead to social and cultural disruption, resulting ultimately in environmental and Malthusian refugees, eco-theologians, ecoterrorism, and environmental warfare. The writings of Asimov and Toffler are contrasted to suggest that with AI techniques, especially knowledge-based systems, many of the features described for psychohistory in dealing with economic, social, and ethical issues are available—or at least are feasible—today. In addition, these AI techniques permit consideration of small groups or individuals as well as large groups.

Psychohistory was described by the science fiction writer Isaac Asimov in his *Foundation* trilogy as providing the ability to "foretell the course of the great social and economic currents ... at that time" (Asimov 1953). By including consideration of items such as "the known probability of Imperial assassination, viceregal revolt, the contemporary recurrence of periods of economic depression, the declining rate of planetary explorations..." (Asimov 1951), psychohistory permitted prediction of wars, revolution, religious development, and the emergence and fall of a wide range of social, cultural, and economic groupings.

Psychohistory was defined as "that branch of mathematics which deals with the reactions of human conglomerates to fixed social and economic stimuli... [with] the assumption that the human conglomerate being dealt with is sufficiently large for valid statistical treatment" (Asimov 1951). It was "the quintessence of sociology; it was the science of human behavior reduced to mathematical equations," and "through the generalization of psychological knowledge from the individual to the group, sociology was also mathematicized" (Asimov 1953).

Toffler (1990), on the other hand, indicates that knowledge, including art, science, moral values, and information, has a crucial role in relationship to power and can substitute for conventional factors of production, such as land, labor, raw materials and capital, with the result that many social and economic changes can be related to changes in the way knowledge is gencrated, processed, and used. This suggests that a knowledge-based (i.e., an AI) approach, rather than a statistical approach, may be more appropriate for dealing with current socio-economic changes. Toffler (1990) also writes, "As politics becomes increasingly de-massified, leaders who once dealt with a few big, more or less predictable political constituencies are seeing these splinter into countless small, temporary, single issue grouplets, continually forming, breaking, and re-forming alliances—all at high speeds." Systems designed to deal with socio-economic and socio-ecological issues must therefore address not only the issues of small size but also of rapid rearrangement and focus of groupings.

In the study reported here, a hypothetical scenario of a natural resource development program forms the basis for examination of a knowledge base and knowledge processing approach that illustrates Toffler's views and exhibits many of the features described for psychohistory. Specifically, the hypothetical example focuses on the building of a new road in a poor region of a Third World country to facilitate resource exploitation in the area. The road links an urban center to a rural area containing a number of villages in which the populations differ in ethnicity. While the scenario focuses on a local situation, there is a growing awareness that local actions in resource management can have global repercussions (Sedjo 1993, 1995; Perez-Garcia 1995; Schallau and Goetzl 1992; Brooks 1995). Defining the scope of the required knowledge to fully evaluate a particular scenario is difficult; scoping of systems is presently a highly subjective process.

Table 1. *Example of knowledge base constructed from the information in pages 1-25 of Blaikie et al. (1994). The facts are in a form that could be understood by the AI language, PROLOG.*

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effect("road network",+,"urban diseases",+,1,16).
effect("urban diseases",+,"disaster vulnerability,"+, 1,16).
effect("road network",+,"access to clinics",+, 1,16).
effect("access to clinics",+,"disaster vulnerability",-,1,16).

effect("road network",+,"arable land",-,1,16).
effect("arable land",-,"famine vulnerability",+,1,16).
effect("road network",+,"access to food sources",+,1,16).
effect("access to food sources",+,"disaster vulnerability",-, 1,16).

effect("road network",+,"drift to cities",+, 1,16).
effect("drift to cities",+,"local labor",-,1,16).
effect("local labor",-,"crop yield",-,1,16).
effect("crop yield",-,"famine vulnerability",+,1,16).
effect("local labor",-,"building maintenance",-,1,16).
effect("building maintenance",-,"earthquake vulnerability",+, 1,16).
effect("local labor",-,"erosion,+,1,16).

effect("drift to cities",+,"migration",+,1,16).
effect("migration",+,"local institutions",-,1,25).
effect("migration",+,"local knowledge",-,1,25).
effect("local knowledge",+,"familiarity with land",+, 1,25).
effect("familiarity with land",-,"income",-,1,17).
effect("familiarity with land",-,"nutrition",-,1,17).
effect("nutrition",-,"malnourishment",+,1,24).
effect("malnourishment",+,"disaster vulnerability,"+, 1,24).
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## The Knowledge Base

A knowledge base containing qualitative knowledge, useful for at least preliminary studies, can rapidly be developed from published information (Table 1). In Table 1, facts have the form:

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effect(Cause, Cause_direction, Effect, Effect_direction,
    Reference_code, Page)
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where Cause is the causal factor, and Effect is the effect of changing the causal factor in a particular direction. Both Cause_direction and Effect_ direction have values of "+" or "-", indicating an increase or decrease. Reference_code is a numeric index to the publication from which the knowledge was inferred, with Page being the specific Page reference. For example, the first fact in Table 1 is:

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effect("road network",+,"urban diseases",+,1,16).
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which indicates that an increase in the road network promotes the spread of urban disease. Reference 1 is Blaikie et al. (1994); this fact was obtained from page 16, from the sentence "The same road may introduce mobile clinics that immunize children against life-threatening diseases, or it may provide the channel through which urban diseases such as tuberculosis and sexually-transmitted diseases arrive with men who had gone to work in city, mine or plantation." Fact number 3 of Table 1 was also obtained from this sentence.

The remaining three facts in the first group of four suggest that increase in urban diseases results in increased disaster vulnerability. However, the increased road network also facilitates access to clinics, which can reduce disaster vulnerability. The second group of facts suggests that the increased road network reduces the amount of arable land, which can lead to famine. However, the increased road network also provides access to alternative food sources, which may alleviate this effect. The third group of facts suggests that the increased road network promotes population drift to the cities, which causes a reduction in the local labor force pool. This has a number of adverse effects, especially as indicated by the fourth group of facts, which show the effects of loss of local knowledge leading to reduced incomes and an increase in malnutrition.

The facts in Table 1 were based on a book with a particular emphasis on natural disasters. These facts would be combined with facts derived from other sources with different emphasis, such as one that examined the opening up of new markets due to the new road network. Facts could also include predictions of increased jobs due to the resource exploitation that was the reason for the road creation in the hypothetical scenario.

When one follows the chain of cause-and-effect relationships in Table 1 after the expansion of a road network, the complexity of potentially favorable or harmful consequences is obvious. Positive effects such as access to resources and services are countered by negative effects of facilitating the drift of people to the cities, resulting in loss of local knowledge and opening the area to urban diseases. The outcome will depend on the specific situation, and may vary in net effect and acceptability from group to group.

Current information extraction technology (Cowie and Lehnert 1996) is at a stage where, in the near future, textual analysis systems will be able to examine digital documents and automatically extract facts of the form in Table 1. In the immediate future, the value of increased understanding may greatly eclipse the value of prediction because even the simple following of the chain of inferences, as described above, may at least make policymakers aware of potential outcomes and help them avoid problems of particular policies.

To move closer to a more predictive system, more specific information must be available. Indicator values may be used at this level. However, the indicators used are often subjectively assigned and vary with the prevailing paradigm (Jazairy et al. 1992). For example, the "trickle down" paradigm was the guide to development projects over the past 40 years, where aid was used to promote overall economic growth in a country, with the assumption that benefits would trickle down to the poor. Rate of growth of GNP, or rate of growth of GNP/capita, was the main indicator of performance.

A new, "trickle up" paradigm, proposed by Jazairy et al. (1992), is based upon enhancing the production capacities, and hence the incomes, of the poor, with the benefits filtering *up* through the economy. Jazairy et al. (1992) developed a number of poverty-related social indicators, including a Food Security Index, an Integrated Poverty Index, a Basic Needs Index, a Relative Welfare Index, and a Women's Status Index. Many of the indicators, which often vary with culture, have environmental components, but quantitative data is often limited. Thomson (1993) discusses the role of AI in dealing with cultural variability in parameters of such indicators.

AN AI APPROACH, RATHER THAN A STATISTICAL APPROACH, MAY BE MORE APPROPRIATE FOR DEALING WITH CURRENT SOCIO-ECONOMIC CHANGES.

The supported actions under the "trickle up" paradigm target specific groups, and the performance indicators reflect this targeting. This is entirely consistent with Toffler's (1990) view that increased knowledge permits customization of actions and products. Indicators of this type may be developed and then subsequently used as inputs to socio-economic models to predict the responses of groups to particular naturally occurring events or planned interventions. New indicators created by these systems can then be used to select among alternative options. Blaikie et al. (1994) discuss a socioeconomic model of households in Nepal where performance indicators, such as destitution or resource accumulation, were predicted using varied coping strategies in scenarios that included natural disasters such as environmental degradation.

In selecting a particular option, such as the development of the new road network in the hypothetical scenario, potential outcomes may vary among groups from good, such as improved nutrition and medical services, to bad, such as increased disease or loss of resources. Some groups will therefore favor the selected option, and other groups may oppose it. Evaluation of the consequences of these opposing opinions requires knowledge about the particular groups.

## Groups

Group size is the fundamental difference between Asimov's and Toffler's theses. The statistical approach of Asimov's psychohistory is rooted in its application to very large numbers of individuals.

> A modern economy presents a picture of millions of people, ... each pursuing their own disparate interests in a rather limited part of the environment. Somehow, these varied individual activities are more or less coordinated and some relative order emerges. Economists commonly explain that this is due to Adam Smith's 'invisible hand,' and that despite the conflicting interests of individuals, the result of their selfish ends is socially satisfactory" (Kirman 1992).

The transition from individual to group behavior has its foundation in the development of social norms (Frank 1992). Thomson (1993) indicates the role of AI in resolving questions such as "How are norms derived?," "Why do groups decide to adopt some sets of norms and reject other?," "What is an enforceable norm?," and "When will norms be bent or broken?" These are issues that are determined by the relationship of individuals to the groups to which they belong.

Through inheritance of characteristics from group to subgroup, and from subgroup to individual, as discussed by Thomson (1993), using a knowledge-based approach for psychohistory applications, as opposed to a statistical approach, offers prediction of behavior to the level of a small group, or possibly even to an individual level, rather than being restricted to very large groups. The approach is based on semantic networks composed of nodes representing objects (in this case an individual), actions, or events, and the links represent the relations among the nodes. An object can belong to more than one net (in this case a group). The different nets, known as "perspectives," represent the different contexts in which the object can be described.

Semantic nets facilitate inheritance of values. Thus, a village could be represented by a set of nodes representing individuals or groups of like-minded individuals. Each node can be defined in terms of membership of particular nets. For example, an individual could belong to the nets member_of_family_X, member_of_religious_group_Y, small_landholder, male, member_of_ community_group_Z. The response of an individual in a particular situation may therefore be predictable from knowledge of the views of the groups to which he belongs, weighted by the relevance of the issue to each group. Conversely, an individual's attributes that are relevant to the functioning of a particular net may be identified, such as a group leadership measure that could weight the final contribution of that net to the overall village decision-making process.

An individual can inherit default values of an attribute over the network, with inheritance being possible over many levels and over multiple networks. If family X is part of clan XX, then an individual could inherit clan attributes through his membership of the family net. The overall response of a village to a particular issue would then be the weighted response of all its networks. In this way, significant effects of ethnic differences among the villages in the example may be predicted.

Expert systems provide a means through which attributes of a particular group can be inferred, as indicated in an example from Colfer et al. (1989):

RULE NUMBER: 11

| | |
|---|---|
| IF: | Ethnicity is Javanese transmigrant |
| THEN: | Landowner is normally considered to be a male household head |
| and | Land is viewed as very limited |
| and | Rights to land are traditionally certified and private |
| and | Women's agricultural labor is recognized as necessary but not preferred |
| and | Ethnicity is symbolized by farming and small-scale female trade |
| and | World view is hierarchical and authoritarian |
| and | Domestic animals may include <2 cows and goats and chickens and 2 or more cattle |
| and | Most crops planted probably require intensive management |
| and | People value fertilizer and hoeing and cattle |

Such systems may be used to infer parameter values to tailor indicators and system parameters to particular groups (Thomson 1993) to facilitate the customization of development programs.

Toffler (1990) suggested that changes in the manner and speed with which knowledge flows through organizations has led to an increase in efficiency, permitting customized delivery of products, programs, and services. However, we lack a system of ethics that can help resolve conflicts between the interests of society and large and powerful organizations; these conflicting interests are manifested in the way in which knowledge flows through organizations (Bella 1992).

## Ethics

The drawbacks of conventional cost-benefit analysis in comparing individual versus community ethics for policy-making are discussed by Partridge (1992). Any approach to valuation and decision-making that puts the requirements of an ecological-economic system above those of the individual requires ethical judgments about the rights of the individual in relation to the rights of future generations (Barbier 1994).

While environmental policies should be based on ethical considerations, the question is, upon whose ethics should they be based (Stoett 1994)? For example, would the code of ethics for land management developed by the Society of American Foresters (Linnartz et al. 1991, Craig 1992) be acceptable to environmental groups (and vice versa)? Ethics and culture are closely interlinked. Peasant perceptions of famine and relief programs are grounded in ethical considerations (Imam 1984). Thus, in the hypothetical scenario, if increased malnutrition is predicted (Table 1), and a food relief program proposed, its likely success can be inferred from understanding the codes of ethics of the different ethnic groups in the area.

Since ethics involves principles and criteria (Schultz 1994), like the law, it should be amenable to AI treatment similarly to legal systems. Thus, in the same manner that expert systems can deal with different ethnic and cultural issues, an AI-based code of ethics can be envisioned. As expert systems can include multiple experts, this system would permit inclusion of multiple codes of ethics, advising where conflicts might arise.

Asimov (1951) emphasized the importance of applying "that much neglected commodity—common sense [facilitated by] that branch of human knowledge known as symbolic logic, which can be used to prune away all sorts of clogging deadwood that clutters up human language." Including "common sense" in computer applications is a major issue in present day AI research (Davis 1990, Davidson 1994). In particular, Davis (1990) addresses the role of AI in relation to common knowledge of human and social interactions, belief systems, ethical values and communication.

Value systems or codes of ethics will determine the response of a group to socio-economic or environmental changes. At this stage, Asimov's psychohistory would predict the particular type of response, such as conflict, development of a new economic paradigm, development of a new social grouping, or a religious development. A brief review of resource-based conflicts indicates potential outcomes.

## Resource-Based Conflicts

In a study of the contribution of scarcities of renewable resources to social instability and strife, Homer-Dixon et al. (1993) indicated that "the social and political turbulence set in motion by changing environmental conditions will not follow the commonly perceived pattern of scarcity conflicts." While resource constraints in general may result in conflict (Choucri 1991), many present conflicts have their origins in access to water (Gleick 1991, Okidi 1991, Myers 1994), at scales down to the local level, such as street fighting over water when the supply is scarce (Fass 1984). In the Sahel zone of Africa, no governments survived the droughts of the 1970s and 1980s (Myers 1994). Water is the root of the eco-wars discussed by Toffler (1990). Toffler also predicts the possible rise of an "eco-theocracy," given a particular pattern of resource disasters.

Access to land and resources is another major source of conflict. Peluso (1992) gives a detailed account of the manner in which changes in access to land in Java has led to an active resistance movement. Acts of ecoterrorism, such as the destruction of the giant tortoises of the Galapagos Islands, are an extreme form of protest in response to resource access issues (Pearce 1995). The Chipko ("tree hugging") movement in the Himalayas, on the other hand, is a non-violent social protest that has helped define the links between technology, ecology, politics, and cultures in that area (Guha 1993). Sudden, drastic changes in land ownership patterns can result in major changes in the patterns of people's lives even in the U.S.A. (Echelberger et al. 1991).

> IF ENVIRONMENTAL POLICIES SHOULD BE BASED ON ETHICAL CONSIDERATIONS, THE QUESTION IS: WHOSE ETHICS?

As access to resources becomes increasingly limiting, "Malthusian refugees" flee from an area in which the population has grown beyond the environment's capacity to support it. When political negotiations at the refugees' destination fail, violence erupts (Hazarika 1991). "Environmental refugees" result when modern development strategies cause environmental degradation leading to population displacement (Suhrke and Visentin 1991, Myers 1994).

Conflicts among different groups on the land base, and between these groups and the state, are often rooted in different systems of knowledge (Banuri and Marglin 1993). Indigenous knowledge systems, or at least an awareness and understanding of these systems, are often the key to successful development programs (Brokensha et al. 1980, de Boef et al. 1993, Kunzel 1993). Inclusion of indigenous knowledge systems in computer knowledge-based systems could therefore enhance the success of development programs. However, the indigenous knowledge may be based on a way of seeing the world that is radically different from anything in Western culture (Wertheim 1995), making it difficult to incorporate in knowledge-based systems.

While the example presented here (Table 1) demonstrated how immediate and local effects of a development program can be predicted, longer term and more remote effects can also be inferred. One such longer term effect might be the resource exploitation leading to erosion and drought, with possible conflict over access to water. Such conflicts can take on religious or racial overtones, and have the potential to escalate to the extent of warfare among nations (Toffler and Toffler 1993). It is evident, therefore, that the possible outcomes of the hypothetical scenario on which this study was based parallel those dealt with by psychohistory. The issue then becomes the ability to predict whether dissatisfied groups will have a peaceful or violent response. A knowledge-based approach to define the characteristics of groups, that would lead to this type of prediction, was discussed above. While AI systems have been developed that predict group activities in counternarcotics (Abramson et al. 1994) and terrorist (Waterman and Jenkins 1986) domains, no studies have yet been carried out in the natural resource domain.

Once an outcome was predicted by Asimov's psychohistory, a particular course of action was also determined. Knowledge-based systems might be developed to determine the optimal action for resource-based issues, in the same manner as AI is used to provide guidance to military operations (Callero et al. 1986).

## Discussion

A global system fulfilling all the functions envisioned in Asimov's psychohistory is not yet here. However, all the essential elements exist or are currently feasible with AI, and knowledge-based systems in particular, providing the link between the natural resource domain and the disciplines of sociology, economics, and cultural anthropology.

Rapid access to detailed knowledge not only permits customization of programs and services, but also results in fragmentation and restructuring of existing groupings (Toffler 1990). The success of a psychohistory system will therefore depend on the ability of the system to keep up with, or even keep ahead of, the changes in groupings. This will entail prediction of group changes resulting from planned or current events or actions. These predictions will in turn rely on automated generation of knowledge bases that include attributes describing the hierarchical affiliations and interconnections among groups, as well as a group's norms and code of ethics.

There is a growing awareness that not only humans require a code of ethics. Robot control systems and, more generally, any autonomous software agents require guidance in a manner analogous to a code of ethics. The psychohistory system itself would therefore require its own built-in, software-based code of ethics. Codes of ethics in autonomous software systems and robots are discussed in Ford et al. (1995).

This study began with one set of Asimov's books, the *Foundation* series, and ends with another: his *Robot* series, based on "The Three Laws of Robotics" (Asimov 1942):

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

As in human codes of ethics, many of the issues relate to the definition and prevention of "harm" (Weld and Etzioni 1994).

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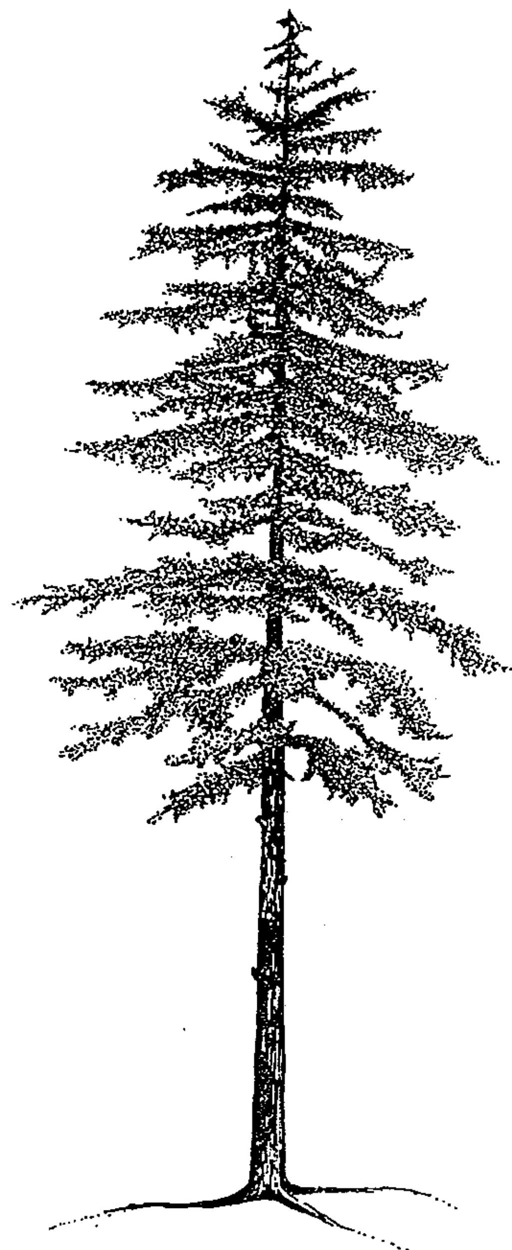

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