Adapting to a Highly Automated World

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Abstract

> *"What is the nature of the engineering experience of our time? What is it like to be an engineer at the moment that the profession has achieved unprecedented successes, and simultaneously is being accused of having brought our civilization to the brink of ruin?" (Florman, The Existential Pleasures of Engineering)*

This paper considers the role of technology in society and the concept of *trust* applied to technological systems. It analyzes the social and technical mechanisms existing for the containment of problems in terms of their capabilities to adapt to a highly automated world. Our adaption to the automated world that we have created requires engineering disciplines to formalize the social dimension of their activities as much as they have formalized the technological dimension. We can "trust" technology only to the extent that we can trust the engineering professions to accept the responsibility for this formalization. The complexity of modern technological systems and the social structures they serve is in danger of going beyond our conceptual capabilities to understand, anticipate and manage. A significant activity of all engineering professions must be to harness the power of modern information technology, of expert and knowledge-based systems, to enhance their abilities to model and manage the impacts of decisions falling within their professions.

1 Introduction

Advances in information technology and robotics have made automation so cost-effective that it has become a major commercial dynamic for an increasing range of industries. It is necessary to automate to remain viable in an environment of rapid change and intense domestic and international competition. While automation affected primarily the production functions of manufacturing units, human concerns have been largely those of job displacement and unemployment. However, automation is also playing a major role in controlling essential functions such as the production of energy, transportation, food supply and health care. This raises questions about the extent to which we are willing to trust information technology and robotics in performing those functions.

There are also environmental consequences of failures of automated systems in a variety of industries that have become major concerns. The residual activities managed by people in automated systems are often those of handling unusual or crisis situations beyond the programming of the system, and a number of major incidents due to the failure of both automated and human functions in a crisis have raised public awareness of the potential dangers in some of the complex systems now in operation. This paper considers the role of technology in society and the concept of *trust* applied to technological systems. It analyzes the social and technical mechanisms existing for the containment of problems in terms of their capabilities to adapt to a highly automated world.

2 Problems of the Information Age

For many years we have been told that we are on the brink of an *information age* (Dizard 1982), a *post-industrial society* (Bell 1973), in which we shall establish different relationships to one another, and to our environment, based on computer and communications technology. Toffler advances the concept of a *third wave* following previous agricultural and industrial waves:

> *"Without clearly recognizing it, we are engaged in building a remarkable new civilization from the ground up... It is, at one and the same time, highly technological and anti-industrial." (Toffler 1980).*

He rationalizes much of the turmoil around the world as "agonies of transition" between two civilizations and, in relation to the individual, notes:

> *"Caught in the crack-up of the old, with the new system not yet in place, millions find the higher level of diversity bewildering rather than helpful. Instead of being liberated, they suffer from overchoice and are wounded, embittered, plunged into sorrow and loneliness intensified by the very multiplicity of their options." (Toffler 1980)*

This emphasis on choice presents a different view of the problems of the information age from those we have come to expect, that computers will be used to restrict our freedom or replace us in the work-place. In *The Conquest of Will*, Mowshowitz fears that computer-based information systems will lead to:

> *"the alienation of individual responsibility which results from excessive bureaucratization of decision-making" (Mowshowitz 1976)*

and Laudon in *Computers and Bureaucratic Reform*, while noting the limited impact of the computer, concludes:

> *"the information systems we describe...illustrate the use of a new technology to further the political aims and interests of established and limited groups in society." (Laudon 1974)*

Fears about job-displacement go back to the early years of computing. Wiener's prophetic statements of 1950 on *The Human Use of Human Beings* are uncomfortably close to reality today:

> *"the automatic machine...is the precise economic equivalent of slave labor. Any labor which competes with slave labor must accept the economic conditions of slave labor. It is perfectly clear that this will produce an unemployment situation, in comparison with which the present recession and even the depression of the thirties will seem a pleasant joke" (Wiener 1950)*

He is also concerned about political abuse and quotes a Dominican friar, Dubarle, reviewing his earlier book, *Cybernetics* in *Le Monde* December 28, 1948:

> *"conceive a State apparatus covering all systems of political decisions...In comparison with this, Hobbes' Leviathan was nothing but a pleasant joke. We are running the risk nowadays of a great World State, where deliberate and conscious primitive injustice may be the only possible condition for the statistical happiness of the masses: a world worse than hell for every clear mind." (Wiener 1950)*

Wiener discounts Dubarle's fears but notes the:

> *"real danger...that such machines, though helpless by themselves, may be used by a human being or a block of human beings to increase their control over the rest of the human race" (Wiener 1950),*

a fear which is prevalent today and is leading, or has led, to highly restrictive legislation governing the access to, and use of, data kept on computers.

A Luddite movement against computers is also conceivable and Weizenbaum's book on *Computer Power and Human Reason* has much in it to excite such a response:

> *"Science promised man power. But, as so often happens when people are seduced by promises of power...the price actually paid is servitude and impotence." (Weizenbaum 1976)*

These words echo Butler's remarks of nearly a century ago about a previous era of high technology:

> *"The servant glides by imperceptible approaches into the master; and we have come to such a pass that, even now, man must suffer terribly on ceasing to benefit the machines." (Butler 1872)*

More recently, Brod in *Techno Stress* has pointed to the human cost of the computer revolution in terms of personal life, noting:

> *"our devotion to the new machine prevents us from seeing the possible consequences of spending long hours—in work and at play—with a machine" (Brod 1984)*

and Turkle (1984) has shown the deep impact of interaction with computers on children's perception of the world.

3 Social Roots of Information Technology

However, is information technology a cause of social problems or part of society's response to solving them? We live in an increasingly over-crowded world where resources are stretched to their limits and all aspects of our existences have become inter- dependent. The Club of Rome reports have drawn attention to the perils involved (Peccei 1982), and there are technologies, such as bio-engineering, that pose far greater threats than does computing (Cherfas 1982). Information technology may be necessary to our survival and the problems that we attribute to it may be side-effects of coping with increasingly complex world dynamics. Thus our concerns about information technology must be set in the context of a model of society as a whole if we are to begin to discern cause and effect.

Ellul (1964) has proposed a model of technology in which it is autonomous, running wild, and adversely affecting our society, values, culture and creativity (Winner 1977). However, these last four are phenomena of the *life world* (Schutz & Luckman 1973) and embedded in its processes. To understand their relations to technology we must view it also as a phenomenon of the life world embedded in its processes, both generated by them and generating them (Blum & McHugh 1984). If we treat technology as autonomous we forget its roots:

"Technology is the human's achievement, not his failing—even though the use he chooses to make of it may be fallen indeed. If the products of human techne become philosophically and experientially problematic, it is, I would submit, because we come to think of them as autonomous of the purpose which led to their production and gives them meaning. We become, in effect, victims of self-forgetting, losing sight of the moral sense which is the justification of technology. Quite concretely, the purpose of electric light is to help humans to see. When it comes to blind them to the world around them it becomes counterproductive. The task thus is not to abolish technology but to see through it to the human meaning which justifies it and directs its use." (Kohak 1984)

Beninger sees the information society as the culmination of a control revolution that commenced in the nineteenth century:

"The Information Society has not resulted from recent changes but rather from increases in the speed of material processing and of flows through the material economy that began more than a century ago. Similarly, microprocessing and computing technology, contrary to currently fashionable opinion, do not represent a new force unleashed on an unprepared society but merely the most recent installment in the continuing development of the Control Revolution." (Beninger 1986)

Luhmann in his work on *Trust and Power* provides a model for society that can encompass technology by postulating complexity-reduction as the fundamental motivation for all our social institutions:

"The world is overwhelmingly complex for every kind of real system... Its possibilities exceed those to which the system has the capacity to respond. A system locates itself in a selectively constituted 'environment' and will disintegrate in the case of disjunction between environment and 'world'. Human beings, however, and they alone, are conscious of the world's complexity and therefore of the possibility of selecting their environment—something which poses fundamental questions of self- preservation. Man has the capacity to comprehend the world, can see alternatives, possibilities, can realize his own ignorance, and can perceive himself as one who must make decisions." (Luhmann 1979)

Luhmann's model seems to underly De Bono's optimism about the role of computers in *Future Positive*:

"By great good fortune, and just in time, we have to hand a device that can rescue us from the mass of complexity. That device is the computer. The computer will be to the organization revolution what steam power was to the industrial revolution. The computer can extend our organizing power in the same way as steam extended muscle power... Of course we have to ensure that the result is more human rather than less human. Similarly we have to use the computer to reduce complexity rather than to increase complexity, by making it possible to cope with increased complexity." (DeBono 1979 pp.18-19)

Wojciechowski (1983) sees the coupled dynamics of complexity processes and information technology as the most recent manifestation of the growth of the knowledge construct in human society, the infrastructure of information acquisition, storage, processing and dissemination that is part of our culture and supports individual and social knowledge processes. He has developed an ecology of knowledge and proposed a set of laws underlying the dynamics of knowledge processes and their role in society. He notes that, while attempts at complexity-reduction are a major social dynamic, the overall complexity of the life-world is increasing and that most human problems are now humanly generated:

> *"Contrary to past epochs, from now on the future of humanity, and indeed the very survival of the human race, is in its own hands. Man will have a future if he is capable of envisaging a positive course for himself and planning for it. The capacity of dealing with the future entails the ability to cope with the present and future problems." (Wojciechowski 1986)*

Information technologies impact society but they are also a product of that society and its needs. We cannot understand their social impact if we view them only as an agent of change and not also as a response to change. The changes wrought by information technology are superficial and reflect far deeper underlying changes in society itself. The emphasis on improved human-computer interaction in current information technology is an indication of our need to control computers and use them to support our humanity rather than be controlled and de-humanized by an increasingly technological society.

4 Social Roots of Information Technology

There is such a variety of opinions on the impact of information technology, and such a wide range of types of consequence, that it essential to have some reasonable conceptual framework within which to discuss them. This framework should be basically humanistic and social rather than technological One possible perspective from which to view the impact of technology is that of Maslow's (1971) *hierarchy of personal needs* which gives the dynamics of personal motivations and priorities. The logic of his hierarchy is that upper level needs are of low priority until lower level ones are satisfied. We need to satisfy basic biological needs before we are concerned with safety, and only when we are safe are we concerned with belonging and so on. Too rigid an interpretation of the this logic is subject to debate (Lederer 1980) but, as a taxonomy, Maslow's hierarchy provides a useful classification of our basic needs and the social, and technological, infrastructures that support them.

The left column of Figure 1 shows Maslow's hierarchy of needs, and the next column shows those social systems that have been set up to aid the individual in satisfying his needs. The next two columns show the beneficial and adverse impacts of technology on the individual and these infrastructures, and the final column shows the roles that information technology is playing in supporting these infrastructures.

- At the first level, *basic biological* needs are:
  - — supported by agriculture, energy industries, housing industries, preservation of the environment, financial systems and physical communications;
  - — beneficially impacted by the automation of agriculture and industry, and the provision of low-cost energy through hydroelectric and nuclear power,;
  - — adversely impacted by the destruction of agricultural land through over-intensive farming based on herbicides and pesticides, and by over-population supported by freely available resources;
  - — dependent on information technology for planning, control and management systems.

Individual needs	Socio-economic infrastructure supporting needs	Beneficial impact of technology	Adverse impact of technology	Information technology
Transcend-ence	Moving beyond and subsuming mental, cultural, social and physical "realities"	Increased access to a variety of cultures & experience	Destruction of non-technological cultures	Extension of imagination, intuition, creativity
Self-actualization	Realizing personal potential; facing life as it is; aesthetics; peak experiences	Increasing availability of time for personal development	Alienation from a de-humanized society	Tools in the hands of individuals to give new perspectives
Esteem	Role in family, work and community; other recognized achievements	Extension of individual capabilities	Deskilling of respected job roles & achievements	Tools in the hands of individuals to perform role better
Belonging	Family, work, religion, politics, entertainment	Tele- & physical communications, mass media	Undermining of logic underlying family structure, job displacement	Networking, bulletin boards, games
Safety	Social norms; police, military, medical, insurance	Tele- & physical communications, nuclear stalemate, robots in risk jobs	High risks & impact, of technological disaster, pollution, biotech accidents	Command & control, crisis decision -making
Basic biological needs	Agriculture, energy, housing, ecology, finance, physical communications	Automation - industry & agriculture, hydro & nuclear power	Destruction of land by chemical farming, over-population	Planning, control, and management

Figure 1 The hierarchy of human needs, its social support and the roles of technology

- At the second level, *safety* needs are:
  - — supported by the establishment of social norms, their enforcement nationally by police forces, and internationally by military forces, the provision of medical care, and systems to offset risk through insurance;
  - — beneficially impacted by the availability of effective tele- and physical communications to deal with disasters, the nuclear stalemate making major wars infeasible, and the use of robots in industrial tasks that are detrimental to human longevity;
  - — adversely impacted by the high risks of technological disasters, the increasing potential impact of such disasters, technological pollution and biological side-effects of genetic engineering;
  - — dependent on information technology for command and control systems, and aids to effective crisis decision making.
- At the third level, *belonging* needs are:

- — supported by the establishment of social institutions to which people can belong, notably the family, employment institution, religious and political associations, and sports and entertainment groupings;
- — beneficially impacted by the availability of effective tele- and physical communications allowing interaction over long distances, and the sense of community provided by participation in mass media events;
- — adversely impacted by the decreasing socio-economic needs for family structures in a world of low-cost resources, state welfare and contraceptives, and by the decreasing availability and stability of working institutions as automation displaces jobs;
- — satisfied by information technology through the increasing communications through electronic networks, the provision of computer-based bulletin boards for special interest groups, and the availability of fantasy games of increasing complexity.

- At the fourth level, *esteem* needs are:
  - — supported by the recognition of significant roles in the family, employment institution, and community, and by the social recognition of a wide variety of other achievements;
  - — beneficially impacted by the use of technology to extend an individual's capability to generate recognized achievements;
  - — adversely impacted by the deskilling of previously esteemed job roles and achievements;
  - — satisfied by the use of information technology to provide tools in the hands of individuals to perform their roles better.
- At the fifth level, *self-actualization* needs are:
  - — supported by the availability of opportunities for realizing personal potential, facing life as it is, artistic and other aesthetic experiences, and peak experiences that go to the very core of a person's being;
  - — beneficially impacted by the increasing availability of time for personal development as the need to work decreases;
  - — adversely impacted by feelings of alienation from an increasingly technological society;
  - — satisfied by the use of information technology to provide tools in the hands of individuals to give them new perspectives on life.
- At the sixth level, *transcendence* needs are:
  - — supported by the availability of opportunities to move beyond conventional perspectives on cultural, social and physical "realities", while subsuming them within the enhanced perspective;
  - — beneficially impacted by the increasing access to a variety of cultures and experience brought about by improved tele- and physical communications;
  - — adversely impacted by the destruction of non-technological cultures through this self same access;

— aided by the use of information technology to extend human imagination, intuition and creativity.

The hierarchy of needs model has some interesting consequences. It suggests a divergence between developed world and third world priorities in the use of technology. For countries where food and energy crises still exist the use of computers in agriculture, energy, communications, and so on, will be the main priority. For the developed nations the use at the lowest levels is taken for granted and the levels of belonging and esteem are where the significant new applications lie.

Divergent views of the impact of computers on employment can also be rationalized in terms of Figure 1. Esteem is enhanced if computers provide the capability to do a task more effectively. However, individuals lose the employment contribution to esteem if their perceived role is undermined, for example, to that of servant to a machine. They also lose the employment contribution to belonging if automation displace their jobs. This is the conflict between those who see information technology as a tool to enhance life and those who see it as destroying the social fabric.

5 Causality and Accountability

Technological disasters, and near disasters, such as Three Mile Island, Bhopal, Chernobyl, the loss of Challenger, and the failure to find any effective cure for AIDS, raise questions as to what extent we can "trust" technology. Our dependence on technology from the small scale activities of everyday life, through the operation of urban infrastructures, to the large scale dynamics of our society, can be frightening when examined in detail. In a sense, we may already place too much trust in technology, and are now beginning to wonder if that trust is justified.

However, like the concept of "autonomy", that of "trust" is not appropriate when applied to technology. We have to be careful both in applying the cause-effect models of physical systems appropriate to technology to society, and also in applying such social constructs as trust to the physical systems underlying technology. Habermas (1981) has emphasized the essential differences between the dynamics of society and that of physical systems. The "laws" that govern human behavior are largely conventions embedded in our society and propagated through our culture. They do not have the necessity of the laws underlying physical systems and their analysis differs in many ways from those of physical systems. Human beings create their future through acts of choice that are constrained by their forward-looking intentions. Physical systems unroll their future through acts of necessity that are determined by their previous states.

These differences, and the interactions between them, show up very clearly in the systemic analysis of the causes and responsibility for a disaster. Figure 2 shows an adverse situation on the far right with the chain of physical causation leading up to it on the left. The critical point in this physical analysis is precisely that at which the chain of causation breaks—that is, where human intervention is indicated because a choice was made. A second chain can then be traced as shown in the vertical direction, that of the *accountability* of the human agents responsible for that choice. The critical point in this social analysis is again precisely at that point where the chain breaks—this time, where human choice was made without adequate authority or justification. This defines the *accountability nexus*, the link from an agent to the responsibility for the disaster.

Thus the question of our trust in technology involves consideration of a two dimensional universe of causality and accountability, and the determination not of links but rather the lack of them. This is what leads to the complexity of the question, and the tremendous scope for debate and differing opinions when problems occur. Real-life situations usually involve many interlinked chains of the form shown in Figure 2, and the 'breaks' are rarely clear-cut. A combination of interdependent causes and interdependent accountabilities are generally involved and both the apportionment of responsibility and the prevention of similar situations are complex problems. However, this is not to say that the situation is so vague as to be unanalysable. Quite the contrary, careful tracing of the chains of causality and accountability is just what is needed to control the possibility of disaster, derive its possible forms and make provision for its containment. This is the peculiar strength of the human species, to anticipate the future and take action in the present to cope with events that will probably not occur.

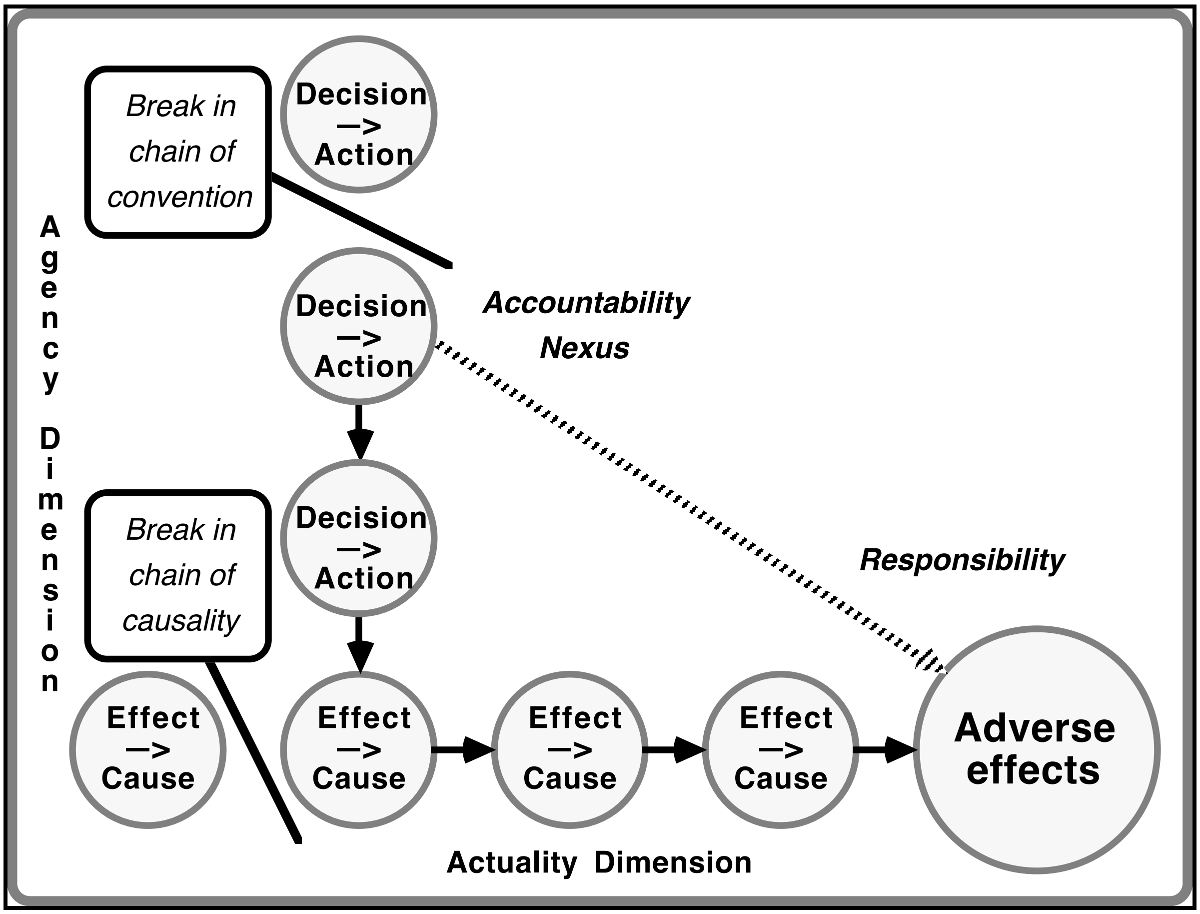

Figure 2 Chains of causality and accountability in determining responsibility

Figure 3 shows the logic of Figure 2 extended to show the dimensions of *impact analysis* of any human choice or decision. It is, perhaps, the clearest distinction between social and physical systems that not only can people be held accountable for the failure to take action, but they can also be held accountable for the failure to anticipate the need for action. As techniques for impact analysis have become more widely recognized, it has become an accountable act of omission not to apply them to any decision that may have significant social or environmental consequences.

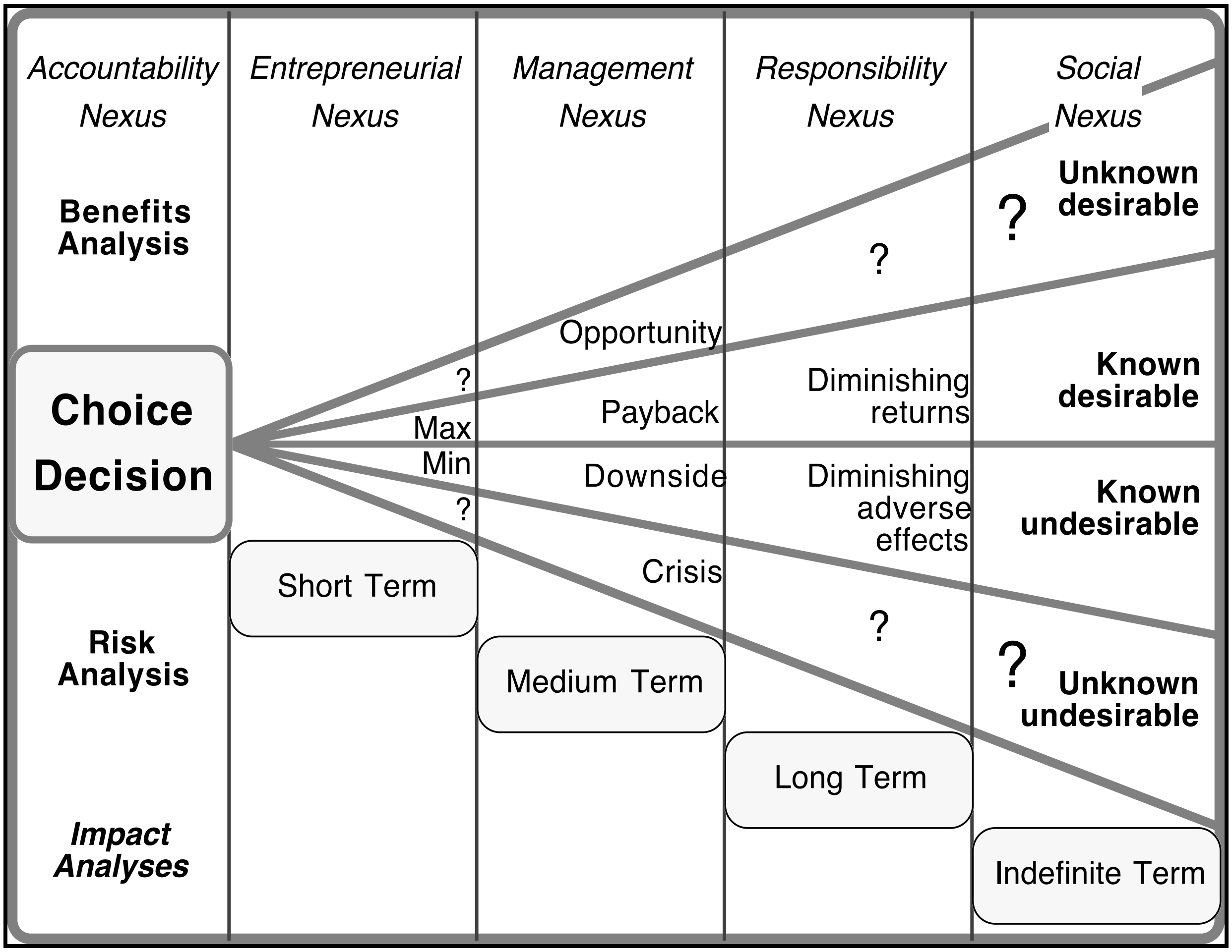

Figure 3 The systems of value, knowledge and impact underlying impact analyses

There are three basic logics underlying Figure 3:

- first, a system of *values* whereby certain consequences of the decision are regarded as desirable and others as undesirable;
- second, a system of *knowledge* whereby certain consequences of the decision are known in advance and others are not;
- third, a logic of *impact* in which certain consequences of the decision are in some regions of impact and others are in different regions.

These regions are, in general, temporal, spatial, social, cultural, economic, anywhere where boundaries may be drawn. Figure 3 shows the temporal dimension divided into short, medium, long, and indefinite term effects:

- the short term is one of the initiating, entrepreneurial activity to implement the decision;
- the medium term is one of the management activity to follow through the consequences of the decision activation, maximizing the desired effects and containing the undesired effects;
- the long term is one of responsibility for the roll-on consequences of the preceding activity when management has moved to other activities;

- the indefinite term is one of society picking up the unexpected consequences of the decision beyond any reasonable responsibility horizons.

It is important to note in Figure 3 that the unknown regions can never be reduced to zero. The future is intrinsically uncertain. Life is risk. We cannot avoid the risk without destroying the dynamics of our social evolution. A static society predicated on the avoidance of unavoidable risk is doomed to extinction. Thus, there will always be the need for secondary activities of crisis management and disaster containment. These are difficult activities economically because by their very nature they involve heavy opportunity costs. It is reasonable to expect that the profit motivation of commercial organizations and the budget limitations of governmental agencies will lead to under-resourcing of such activities. Hence, it is particularly important that the engineering professions establish standards to be applied routinely to the provision of crisis management and disaster containment systems.

It is also important to note that all assessments in Figure 3 are based not on “reality” but upon our *models* of it. We gather data about the world, model it, and then use the model to evaluate costs, benefits, impacts, uncertainties, and so on. The validity of these estimates is limited by the validity of our models and no amount of sophisticated technical analysis can go beyond the limitations of an inadequate model. This places great emphasis on our capability to keep our models up to date, to learn from experience. It again emphasizes the need for crisis management—models tend to underestimate the likelihood of disaster just because disasters are so infrequent. We have to make the basic assumption that our models will always be wrong in this respect.

I have emphasized the systemic, logic principles underlying the analyses of Figures 2 and 3 because the formalization of accountability and impact analysis is essential to the proper engineering management of the role of technology in our society. *Knowledge-based* computing systems provide tools for the formal modeling of complex situations in terms of the logics of value, knowledge, space, time, and so on. *Knowledge support systems* are necessary to provide people with the capability to assume responsibility for full-scale, routine impact analysis. Technology both generates the problems and provides the solutions. It is up to the engineering community to ensure that the solutions are at least one step ahead of the problems. Ultimately, that is where accountability for “trust” in technology lies.

6 Conclusions

Technology is not autonomous but arises out of the needs of society. Its application and dynamics can be understood fully only through analysis of the system of interaction of causality and accountability in technological and social processes. Our adaption to the highly automated world that we have created requires engineering disciplines to formalize the social dimension of their activities as much as they have formalized the technological dimension. We can trust technology only to the extent that we can trust the engineering professions to accept the responsibility for this formalization. Our track record on the small scale is good — professional liability for engineering decisions is well established and managed — but there is reasonable suspicion of our capabilities in the large. The complexity of modern technological systems and the social structures they serve is in danger of going beyond our conceptual capabilities to understand, anticipate and manage. The “unknown” regions in Figure 3 are growing dangerously large.

A significant activity for all engineering professions must be to harness the power of modern information technology, of expert and knowledge-based systems, to enhance their abilities to model and manage the impacts of decisions falling within their professions. This is the challenge of the decade leading into the next millennium—to put social accountability on as solid solid foundations as our models of the physical world, and to build a secure future on these foundations.

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